EXHIBIT B

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Certified Translation

Furnished on the **5th** day of **March, 2021**

I, Alexander Largaespada (), hereby certify that I translated the attached document from Spanish into English or English into Spanish and that this translation is an accurate and faithful translation of the original document. Furthermore, I certify that I am proficient in translating both Spanish and English and that I hold the capacity to render and certify the validity of such a translation. This document has not been translated for a family member, friend, or business associate.

I, Salvador G. Ordorica, as a Quality Assurance Agent of The Spanish Group LLC, hereby attest that the aforementioned translator is a proficient Spanish-English translator. Accordingly, as an authorized representative of The Spanish Group, I certify that this document has been proofread and that the attached document is a faithful and authentic translation of its original.

Respectfully,

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Salvador G. Ordorica
The Spanish Group LLC
(ATA #267262)

Secretariat of Communication and Transport
Undersecretariat of Transport
Federal Civil Aviation Agenda
Aviation Accident and Incident Analysis Directorate
Aviation Accident and Incident Investigation and Judgment Committee

BASIC INFORMATION:

ACCIDENT FINAL REPORT
PROBABLE CAUSE REPORT

FILE No. **ACCDTARA004/2018MMPB**

Aircraft: Agusta Brand, Model A1095, Serial Number 22174, Registration XA-BON.

Operator: Servicios Aereos del Altiplano, S.A. de C.V.

Place: Municipality of Santa Maria Coronango, State of Puebla.

Date and Time: 02:35:40 p.m. (20:35:40 UTC); December 24th, 2018.

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Content

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WARNING

The Aviation Accident and Incident Analysis Directorate, AFAC/SCT, through the Aviation Accident and Incident Investigation and Review Commission, states that this Final Accident Report is based on Annex 73 to the Convention on International Civil Aviation (OACI) and on Articles: 1, 2 section I, 14, 16, 18, 26, and 36 section XXVII of the Organic Law of the Federal Public Administration; 2 section XVI, sub-section XVI.5, 9, and 21 section XXII I of the Internal Regulations of the SCT; 81 of the Civil Aviation Law; 189 and 190 of the Regulations of the Civil Aviation Law and 7.9 of the Organization Manual of the General Directorate of Civil Aeronautics (now the Federal Civil Aviation Agency) and the Mandatory Letter CO AV-83.1/07, and in which it is not an obstacle to note the following:

This Probable Cause Final Report is a technical document that reflects the point of view of the Commission for the Investigation and Assessment of Aviation Accidents and Incidents (CIDAIA) of the Federal Civil Aviation Agency (AFAC) of the Secretariat of Communication and Transport (SCT), regarding the circumstances in which the event subject of this technical investigation took place, identifying the probable cause and contributing factors and the preventive recommendations to all administrative authorities, air transport and airport concessionaires or permit holders, as well as to the aeronautical technical personnel involved in the operation of a rotary wing aircraft.

In accordance with Annex 13 (Investigation of Aviation Accidents and Incidents) of the Convention on International Civil Aviation (CACI); Articles 81 of the Civil Aviation Law and 185 of the Civil Aviation Law Regulations, the main objective of the investigation of aviation accidents and incidents is to prevent and avoid the recurrence or reoccurrence of similar events. The purpose of this activity is not to determine the guilt or civil or criminal liability of those involved in the event, nor to establish legal responsibilities.

Consequently, the dissemination, distribution, copying and other use of the information in this Final Accident Report for purposes other than the prevention of future accidents may result in erroneous conclusions and interpretations.

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Abbreviations and Glossary.

AD	Airworthiness Directives
AFAC	Federal Agency of Civil Aviation, SCT
ALAR	Approach and landing accident reduction
ATIS	Automatic Terminal Information Service
CACI	International Civil Aviation Convention
CFIT	Controlled Flight into Terrain
CIDAIA	Aviation Accident and Incident Investigation and Review Commission
CIMA	Colegio de Ingenieros Mexicanos en Aeronautica
Commission	CIDAIA
CPAM	Colegio de Pilotos Aviadores de Mexico
CRM	Crew Resource Management
CTA	Air Traffic Controller
DAAIA	Aviation Accident and Incident Analysis Directorate
DEBRIS	Debris (material of small dimensions and weights)
EASA	European Aviation Safety Agency
FDR	Flight Data Recorder
FMS	Flight Management System
IAC	Researcher in Charge
IFR	Instrument flight rules
ILS	Instrument Landing System
LOC	Localizer
m	Meters
MEL	Minimum Equipment List
METAR	Meteorological Aerodrome Report
MM	Maintenance Manual
MMEL	Master Minimum Equipment List
OACI	International Civil Aviation Organization
PHP-PAL	Precision Accesories & Instruments
P&W	Pratt and Whitney
RFS	Rotor Flight Services, S. A. de R. L. de C. V
RTAR	Restricted Aeronautical Radio Telephonist
RTARI	Restricted Aeronautical Radio Telephonist with English language proficiency
SAA	Servicios Aereos del Altiplano, S. A. de C. V.
SAS	Stability Augmentation System
SCT	Secretariat of Communication and Transport
SPECI	Special airfield weather report (in meteorological key)
TAF	Airfield forecast (in meteorological key)
TC	Type Certificate
UTC	Universal Time Coordinated
VFR	Visual Flight Rules
Z	Zulu time or UTC

Symbols.

°	Degrees
ʻ	Minutes
ʻʻ	Seconds
deg	degrees
kt	Knots
MN	Nautical miles
Km	Kilometers

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FINAL REPORT

Registration 3 33:	**XA-BON**
File number:	**ACCDTARA004/2018MMPB**

Introduction.

On December 24, 2018, around 2:35:40 p.m. (20:35:40 UTC[1]) the Helicopter Agusta brand, model A109S, serial number 22174, registration XA-BON, owned by Servicios Aereos del Altiplano, S.A. de C.V., (SAA) crashed while covering the flight from Puebla City to Mexico City under visual flight rules (VFR); in control of the helicopter a commander (pilot) and a first officer (co-pilot), both with valid commercial helicopter license, with three passengers on board, crashing in a crop field. The helicopter was destroyed by impact and fire and all five occupants were fatally injured.

According to the audio of the helicopter communications with the Puebla Air Traffic Control Tower (TWR PBC), at 20:34:77 UTC (Coordinated Universal Time), the helicopter registration XA-BON was reported leaving the heliport "El Triangulo" in the City of Puebla with destination to the heliport "Radio Capital" located in Mexico City, at 20:35:40 UTC the last instruction issued by the Air Traffic Controller (CTA) of TWR PBC to the XA-BON is established, indicating it to report 2 nautical miles (MN) before crossing the Puebla Airport (PBC), however the helicopter XA-BON no longer communicated, immediately the CTA tried to communicate several times with XA-BON without success, and then informed the PBC of the loss of communication with XA-BON to initiate the search and rescue efforts.

Furthermore, residents notified the authorities that an "*aircraft*" had *"crashed"* in a field located in the Municipality of Santa Maria Coronango, State of Puebla; this helicopter had traveled a distance of 7.45 MN (13.8 Km) from its takeoff point without the crew reporting on the TWR PBC frequency the existence of any type of emergency on board.

The investigation of this air accident was carried out based on international standards and recommended methods established in Annex 13 to the International Civil Aviation Convention, the national notification of the accident was made by the Aeronautical Authority of Puebla Airport (representative of the State of Registration) so that the Directorate of Analysis of Aircraft Accidents and Incidents (State of the Event) implemented the investigation making the international notification since the day of the occurrence of the accident.

Based on the above, the State of the Manufacturer was notified through its Accredited Representative Agenzia Nazionale per la Sicurezza del Volo (ANSV), its Technical Advisors Leonardo Helicopters and EASA (European Union Aviation Safety Agency); the Accredited Representative of the State of Manufacture of the engines; Transportation Safety Board of

[1] On the date of the accident the difference between local time and Universal Time Coordinated (UTC) was 6 hours.

Canada (TSB) and finally the National Transportation Safety Board (NTSB) as the representative of the manufacturer of the electronic components installed in the helicopter; and as part of the investigation process the following consultants were called in: Colegio de Pilotos Aviadores de Mexico A.C. and Colegio de Ingenieros Mexicanos en Aeronautica, A. C.

This Probable Cause Final Report was sent to the above-mentioned States through their Accredited Representatives to consider their comments, which were included in this report, in terms of OACI Annex 13.

The responsibility for the implementation of the safety and/or technical recommendations emanating from this accident report lies with the recipient of the notification of the recommendation.

The follow-up of the recommendations contained in this report corresponds to the Aeronautical Authority, through its verifications.

The Aircraft Accident and Incident Investigation and Review Commission emphasizes that in no case does the Probable Cause of this accident, the contributing factors, the recommendations issued in this Probable Cause Final Report or the contents of its annexes indicate responsibility or liability for the occurrence of the event.

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1. **FACTUAL INFORMATION**.

1.1. **Overview of the flight**.

The helicopter provided public passenger service in the form of domestic non-scheduled air cab, the owner of the helicopter [Servicios Aereos del Altiplano, S. A. de C. V. (SAA)], which entered into a contract with the aeronautical workshop Rotor Flight Services, S. A. de R.L. de C.V. (RFS) to provide "*Operation, application of the Maintenance Program, application of Directives and Technical Bulletins, correction of discrepancies*[2]*, Pre-flight and Post-flight Inspection and Administration*".

According to the maintenance records provided by the RFS workshop it came to our attention that on December 13, 2018 the technical staff (one inspector and one avionics technician) generated discrepancy form 21/2018, stating:

> ***"(...) BY LOGBOOK REPORT FOLIO 1043*[3] *AND UPON PERFORMING OPERATION TESTS ACCORDING TO MM REF. 0B-A-22-11-00-00A-340A-A. THE LINEAR ROLL ACTUATOR WAS FOUND DAMAGED*[4]*. IT REQUIRES REPLACEMENT (...)" [sic]***, noting in the remarks section of said document that: ***"(...) SAID ACTUATOR WAS INSTALLED ON SEPTEMBER 10, 2018 WITH T.T A/C: 2063:02 HRS IN REPAIRED CONDITION. IT HAS ONLY OPERATED 102 HRS (...)" [sic].***

During interviews with the technical personnel who performed this task, they stated that they performed the corresponding trouble shooting[5], isolating the fault in the roll actuator of the Stability Augmentation System (SAS2), noting that it required replacement.

As of December 13, 2018, the helicopter continued to operate without the technicians having recorded in logbook that the SAS2 was out of service, in accordance with the Minimum Equipment List (MEL) and that replacement of the affected component was required no later than December 17, 2018, in accordance with the authorized MEL of Servicios Aereos del Altiplano.

The MEL of the air operator also states that the operation of the helicopter may be performed in visual flight conditions and observing the restrictions of the Flight Manual until the expiration date indicated in the MEL, with no prolongation of the operation.

There is evidence of e-mails dated December 19, 2018 from Rotor Flight Services, S. A. de R.L. de C.V. (RFS) and Precision Accesories & Instruments (PHP-PAL) in Atlanta, Georgia where they initiate the warranty claim procedure for the roll actuator.
In one of these emails, it is stated the following:

> ***"(...) The client tells me that if it is removed, the machine will be out of service and the work schedule is a little busy right now, so it is not possible to stop or leave it out of service these days. We are also trying to find a way to prevent the machine from being out of service (...)". [sic].***

(see image 1 of Attachment A).

[2] Report of a failure or malfunction of a part, component or system of the helicopter, issued by aeronautical technical personnel.
[3] Folio 1043 of the flight log, has the date December 8, 2018 recorded on it.
[4] According to the interviews conducted with the maintenance technicians, they indicated that there was no physical damage to the actuator that they only wanted to describe with the term "DAMAGED", that the actuator was not working properly.
[5] Detection of failures using techniques provided by the helicopter manufacturer.

On December 20, 2018, technicians from the Rotor Flight Services workshop performed the replacement of the lower half scissor of the swashplate, due to excessive play, closing the discrepancy format 20/2018, whose opening was on December 4, 2018 and releasing the XA-BON helicopter for operation.

The helicopter operated again until December 22, 2018 performing the following air operations:

Origin	Destination	Departure time UTC (hours)	Arrival time UTC (hours)	Flight time
HPW[6]	HAQ[7]	14:30	14:34	00:04
HAQ	SAI[8]	15:05	15:32	00:27
SAI	MEX[9]	15:37	15:42	00:05
MEX	SAI	19:01	19:10	00:09
SAI	AOC[10]	19:14	19:40	00:26
AOC	PBC	19:44	19:54	00:10
			TOTAL	***01:21 hours***

According to the data provided by the air operator, the helicopter operated on December 23 performing the following flights:

Origin	Destination	Departure time UTC (hours)	Arrival time UTC (hours)	Flight time
PBC	VIR[11]	16:30	16:53	00:23
VIR	APA[12]	17:15	17:35	00:20
APA	PBC	17:39	17:53	00:14
			TOTAL	***00:57***

On December 24, 2018, the crew entered an electronic flight plan where it was established that the XA-BON would take off from the air operator's hangar at the PBC airport at approximately 1:15 p.m. (19:15 UTC), as the proposed time, bound for the El Triangulo heliport (HAQ), under visual flight rules, at a speed of 140 knots, at 9,500 feet, estimated 10 minutes of flight time. According to the interview with the operator's ramp personnel (signalman), he indicated that the captain sat on the left side and the co-pilot sat on the right side.

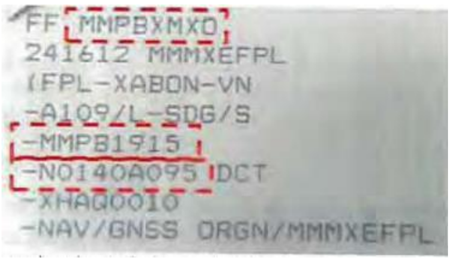
FF MMPBXMXD
241612 MMMXEFPL
(FPL-XABON-VN
-A109/L-SDG/S
-MMPB1915
-N0140A095 DCT
-XHAQ0010
-NAV/GNSS ORGN/MMMXEFPL

Fig. 1.1.1. Electronic flight plan sets a speed of 140 knots.

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[6] Puebla State Government Heliport
[7] El Triangulo heliport, in Puebla
[8] San Angel Inn Heliport in the CDMX
[9] CDMX Airport heliport area
[10] Acocotla Atlixco Puebla
[11] Virreyes Heliport in the CDMX
[12] Apan, Hidalgo

According to the tape transcription of the audios from the Puebla Control Tower, it is observed that the XA-BON helicopter took off at 1:34:12 p.m. (19:34:12 UTC) from the Puebla Airport, that the crew notified the Control Tower of the long landing in el Triangulo and that they would be pending for the new departure, however, it actually landed in the yard of a house located at the coordinates see reference 1; at 1:39:22 p.m. (19:39:22 UTC). According to the investigations, an Operations Officer of the Government of the State of Puebla was in the courtyard used for the landing at the house, who stated that upon the helicopter's landing, the crew proceeded to cut (turn off) the engines and descend from the helicopter, in preparation for takeoff for the next leg of the flight indicated that the first to board and start the engines was the captain, noting that he sat on the right side of the cockpit, after the three passengers boarded, the co-pilot closed the passenger cabin door and proceeded to climb in and sit on the left side of the cockpit, this being the co-pilot's position.

From the information of Servicios a la Navegacion en el Espacio Aereo Mexicano (SENEAM), in the transcription of the communications between Control Tower Puebla (TWR PBC), it is observed that the helicopter took off at 2:34:17 p.m. (20:34:17 UTC); in the audio of the TWR PBC frequency, it is heard that the co-pilot of the XA-BON reported:

> ***"...leaving el Triangulo (HAQ) by Radio Capital (HUM)..." [sic]***

It is noted that there is no evidence of the position in which XA-BON was in space, at the time the co-pilot notified that they were taking off; it is also heard that station data and authorization is requested to cross Puebla Airport (PBC) and proceed to Radio Capital (HUM) in Mexico City, so the Air Traffic Controller (CTA) of TWR PBC provided him with altimetry correction information **"thirty twenty-seven" [sic]** and instructs him as follows:

> ***"call two miles ahead to cross the station" [sic].***

As there was no collation of the instruction, at 2:35:16 p.m. (20:35:16 UTC) the TWR PBC ATC proceeded to call the XA-BON and asked if they had received the instruction, indicating the XA-BON co-pilot:

> ***"(...) we turned the radio back on..., eh, I didn't copy you, now we are, eh..., six points six miles from the Airport and we are going by Radio Capital" [sic].***

The TWR PBC ATC provided again the altimetry correction information and informed him that there were no transits, to call crossing over the station to continue his flight, the XA-BON correctly confirmed the information, at 2:39:29 p.m. (20:39:29 UTC) the TWR PBC ATC asked the XA-BON if he had already flown over the station without receiving an answer, 20 seconds later he tried to communicate again without obtaining an answer, the TWR PBC ATC made 9 more attempts, without obtaining an answer.

TWR PBC ATC proceeded to contact Puebla State Government operations and the Puebla Airport Command (Search and Rescue Coordination Center), minutes later the Search and Rescue Coordination Center indicated that the C4 (Civil Protection of the State of Puebla) reported a helicopter crash; At 3:09 p.m. (21:09 UTC) three search and rescue aircraft went out to locate the crash site, subsequently reporting that the helicopter was on radial 114° at 2.5 nautical miles (MN) from the VOR (air navigation aid) at the Puebla Airport (PBC) and notifying that there were no survivors. The helicopter was destroyed by impact and fire, the two pilots and three passengers were fatally injured.

The accident site was located at coordinates 19° 08' 29.47" North Latitude and 98° 19' 49.33" West Longitude, belonging to the Municipality of Santa Maria Coronango, Puebla, in a crop field.

It is known through various media and social networks that the Second Section of the Navy's General Staff informed the public that the ELT (Emergency Locator Transmitter) radio beacon of the helicopter had been activated nine minutes after takeoff, at 2:43 p.m., the Puebla Airport Command (Search and Rescue Coordination Center), indicates that the first communication from the controller searching by aeronautical frequency to the XA-BON was initiated at 2:39:29 p.m.(20:39:29 UTC) and the controller did not respond to his call, initiating the alert phase (Alert).

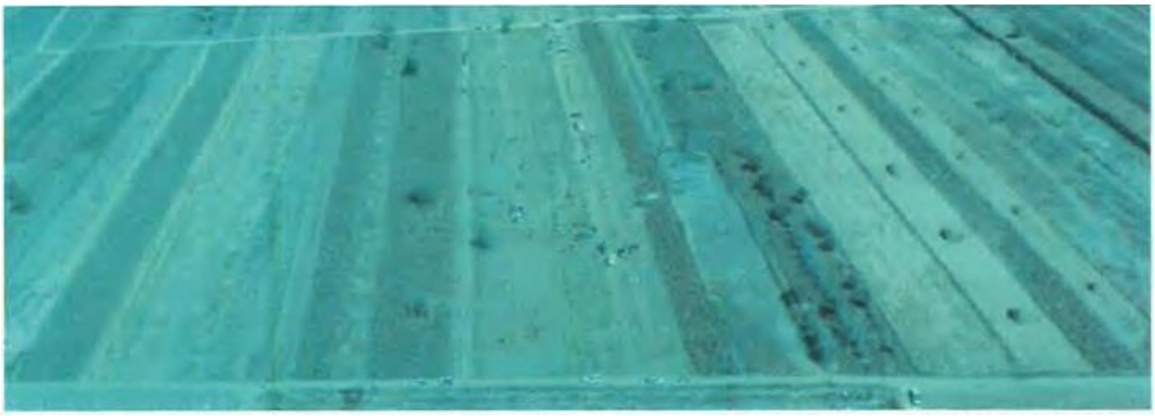

Fig. 1.1.2. Exterior and interior cordon at the accident site, placed by the Attorney General's Office of the State of Puebla.

The municipal police were the first official responders, cordoning off the site; the San Pedro Cholula Fire Department arrived at approximately 2:55 p.m. (20:55 UTC), managing to extinguish the fire completely at approximately 3:25 p.m. (21:25 UTC).

The work of the field investigation was coordinated, determining together to allow the entry of the agencies that required to locate evidence of attacks and explosives; once the authorities that met in the area of the accident concluded their work and delivered the site of the accident and the remains of the XA-BON, the technical field investigation in aviation matters would begin.

The first Unit (Secretariat of the Navy) to enter the accident site was staffed by explosives experts, who determined the following:

> ***"(...)... has informed the working group that its fire and explosives experts, after an exhaustive and careful analysis of the remains of the aircraft, did not find explosives or substances other than fuel that had exploded inside the crashed aircraft(...)" [sic].***

The Aviation Accident and Incident Analysis Directorate received the chain of custody from the Puebla State Prosecutor's Office, initiating the civil aeronautics investigation, therefore, at the end of the field investigation, the helicopter remains were moved to an area where they could be inspected and not kept at the site of the event, continuing only with the foreign investigation entities that would support Mexico, (TSB, NTSB, and ANSV) as well as their advisors: EASA, P&W, Leonardo Helicopter Division and Honeywell (without physical presence at the site).

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In the initial tasks of the investigation, the following was detected:

- The co-pilot was performing communications with the Puebla Control Tower, he was seated on the left side of the cockpit and the captain was the pilot flying and was seated on the right side, and
- The captain was the pilot flying and was seated on the right side.
- In the Limitations section of the helicopter's Flight Manual, the manufacturer indicates that this helicopter is certified to perform any type of operation, with 01 Single Pilot[13]; although the airworthiness certificate issued by the DGAC (now AFAC), stipulates 2 pilots for the operation of this helicopter.

Fig. 7.7.3. The main remains were concentrated at a single point of impact, there was no ground displacement.

- The DGAC (AFAC) has established, through a bulletin, the limitation to operate twin-engine helicopters with two crew members, capable of performing instrument flight rules (IFR) and flying in airspace with high traffic density or in offshore operations, regardless of the manufacturer's certification.
- The XA-BON reported to Puebla Control Tower, informing that it was leaving the heliport called "***El Triangulo***", however, they took off from the patio of the house located at the latitude coordinate See reference 1 [redacted], in the City of Puebla.
- Interviews were conducted with witnesses, who described that they observed the helicopter flying steadily, heard an engine noise and then the helicopter began to "rattle" (the witness described this by making small movements in the yaw axis with his hand), then turned on its longitudinal axis (roll) and finally impacted upside down and nose first against the ground, counterclockwise in the direction of the flight path.

The statements obtained are congruent with the impacts observed in the field during the field investigation, so, based on this initial evidence, the scope of the investigation was determined and focused on a field analysis of the remains and the recovery of non-volatile memories.

[13] According to the Flight Manual, the minimum flight crew required is one (01) pilot operating the helicopter from the right-side seat. The left seat may be used for a co-pilot when dual control is installed.

Fig. 1.1.4. Accident site, with respect to the house where the XA-BON landed and took off.

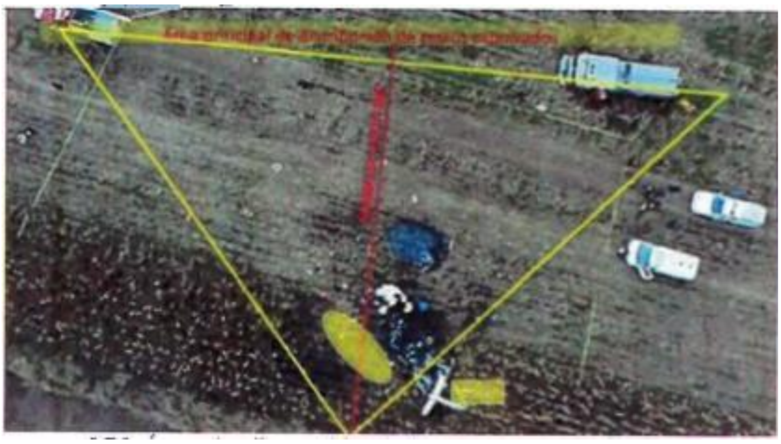
1.2 Injuries to persons

	Fatal	Serious	Minor	Not injured
Pilot	1	--	--	--
Co-pilot	1	--	--	--
Passengers	3	--	--	--
Total	***5***	--	--	--

1.3 Damage to the helicopter

Evidence indicates that the helicopter impacted inverted against the ground, with an estimated inclination of 60°, catching fire immediately; therefore, the basic body, its components, instruments, electronic devices, parts and accessories were completely consumed by the fire.

Some small fragments of the helicopter were scattered over a triangular area of approximately 600 m^2 (6,460 ft^2).



1.3.1 Helicopter remains dispersion area

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Some components of the aircraft were found destroyed, but without fire damage, such as the two engines of the power plant, the core and main transmission, the main rotor, the hydraulic servo-actuators and the main shafts; the root of the main blades and the tail rotor showed damage characteristic of having been rotating at the time of impact, without destruction by fire.

The rear section of the boom, the stabilizers, the tail rotor gearbox (90° box), as well as the core and blades of the tail rotor, showed major damage, without fire damage; some parts of this section were detached upon impact.

The electronics, the crew and passenger cabin seats, as well as the landing gear, were found embedded in the ground, all destroyed by fire.

1.4. Other damages.

The land where the helicopter crashed corresponds to an area destined for planting, where fuel, hydraulic liquid and oil were spilled, without detriment to the fire that occurred.

The main impact caused a 5.70 m (78.70 ft) long, 3.30 m (70.8 ft) wide and 7.20 m (4.0 ft) deep cavity ("crater") in the ground.

1.5. Information of aeronautical technical personnel.

1.5.1. Pilot in command

The citizen **See reference 2**, of nationality **See reference 2** was the holder of a Commercial Helicopter Pilot license, effective February 16, 2021; with the ability to operate helicopters as Pilot in Command of Bell-407, Agusta A109S and A119, instruments, multi-engine and RTAR.

He had an APT psycho-physical fitness certificate, without observations or restrictions by the examining physician, valid as of February 13, 2019; his comprehensive psychophysical examination was performed on August 13, 2018, and was valid on the day of the accident.

From the investigation and from statements obtained, it was observed that he had experience on the route.

In July 2016 he joined the company Servicios Aereos del Altiplano, in November 2016 he accredited the course of Human Factors in Aviation (CRM), in December 2016 the course of Normal and Emergency Procedures in Agusta A119 -Koala equipment, in July 2017 the CFIT/ALAR course and in March 2018 the course Recurrent VFR/IFR in A109S equipment, in the content of this course normal, abnormal and emergency procedures are taken in simulator.

From June 16, 2016 to December 24, 2018, he accumulated 880 hours on A109S and A109 equipment.

He had 5,023.6 total flight hours of experience as of the date of the accident, the last three months prior to the accident, he accumulated the following times, all of these hours were in the XA-BON:

Month	Flying hours
October	30.0
November	30.7
December	30.0

Total	90.7

The last seven days prior to the accident he accumulated: 09:41 hours, all in the accident equipment.

Day	Flying hours
Dec-17-2018	01:07
Dec-18-2018	02:49
Dec-19-2018	02:55
Dec-20-2018	----
Dec-21-2018	----
Dec-22-2018	01:41
Dec-23-2018	01:09
Dec-24-2018	----
Total	09:41

The commander made a flight as pilot monitoring on December 24, 2018 at 1:34:12 p.m. (19:34:12 UTC) and landed at 1:39:22 p.m. (19:39:22 UTC); this flight had a duration of 00:05:10 hours; he subsequently made a second flight as pilot in command, taking off at 2:34:17 p.m. (20:34:17 UTC), which corresponds to the one of the accident under investigation.

1.5.2. First Officer

The citizen See reference 2 of nationality See reference 1 years old, held a Commercial Helicopter Pilot in Command license, valid as of September 13, 2021, and had the capacity to operate helicopters as a pilot in command of Agusta A109S instruments, multi-engine and RTARI level 4.

He had an APT psycho-physical fitness certificate, with the observation of the use of glasses for near vision, by the examining physician valid as of March 25, 2019, his comprehensive psychophysical examination was performed on September 25, 2018.

From the investigation and from statements obtained, it was observed that he had experience on the route.

On April 5, 2012, he obtained the certificate for theoretical training of the initial course for Agusta A-119 MKII (Koala) and A109S (Grand) pilots at the Aeroanahuac Aeronautical Training Center.

He had 7 years of seniority in SAA, in June 2017 he took the CFIT/ALAR course, in June 2018 he accredited the Human Factors in Aviation (CRM/ADM) course, in July 2018 the Normal Procedures and Emergency course in Agusta A109S equipment and in July 2018 the periodic pilot course in A109S equipment.

According to the flight hours check updated to August 10, 2018, provided by SAA, he had 1,072:19 hours of experience in the A109S model helicopter.

The last three months prior to the event, he accumulated the following times, all on A109S equipment:

Month	Flying hours
October	0.2
November	3.2
December	12.7

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Total	16.06 hours

The seven days prior to the accident, he flew 04:06 hours in the XC-LMO equipment, an Agusta helicopter model A109S, of the Government of the State of Puebla.

Day	Flying hours
Dec-17-2018	----
Dec-18-2018	01:30
Dec-19-2018	----
Dec-20-2018	01:15
Dec-21-2018	01:21
Dec-22-2018	----
Dec-23-2018	----
Dec-24-2018	----
Total	04:06

The co-pilot made a flight as pilot flying on December 24, 2018 at 1:34:12 p.m. (19:34:12 UTC) and landed at 1:39:22 p.m. (19:39:22 UTC), this flight had a duration of 00:05:10 hours, then made a second flight as pilot monitoring, taking off at 2:34:11 ho p.m. urs (20:34:17 UTC), which corresponds to the one of the accident under investigation.

1.5.3. Quality Control Inspector

The citizen See reference 2 of nationality See reference 2, holds a class I Maintenance Technician License, valid as of January 25, 2020; he is qualified in Helicopters and Engines.

He has an APT psycho-physical fitness certificate, valid as of January 18, 2021, without any observation or restriction from the examining physician.

In December 2017, he took the periodic course on Agusta Westland 109 SERIES equipment; he took in November 2015 the previous course on the same equipment, in August 2018, he was certified in the Inspection Techniques course.

This quality control inspector was the one who inspected the removal and installation of the MVA[14]; he also supervised, together with an avionics technician, the replacement of the roll linear actuator of the SAS2.

Thirty days before the accident he had these work shifts, being available 24 hours a day.

	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
October	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T
November	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	
December	D	D	D	D	D	D	D	D	D	D	D	D	T	T	T	T	T	T	T	T	T	T	T	T							

D= Day off
T= Working Day

[14] MVA, Mast Vibration Absorber.

JACT / ECG / MAHG / ESM / MHP
[Illegible Signatures]

1.5.4. Quality Control Inspector.

The citizen See reference 2, of the nationality: See reference 2 holds a Class I Maintenance Technician License, valid as of October 12, 2021, with fixed wing aircraft, engines and helicopters capabilities.

He has an APT psycho-physical fitness certificate, valid as of September 28, 2020, with no restrictions from the examining physician, except that he is required to wear glasses.

In August 2018, he took the periodic course on Agusta A109S equipment, the previous course on the same equipment was given in September 2016.

This inspector was the one who inspected the works for the change of the rotary half scissor carried out on December 20, 2018.

Thirty days before the accident, he had this work shifts, available 24 hours a day.

	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
October	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D
November	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D
December	T	T	T	T	T	T	T	T	T	T	T	T	D	D	D	D	D	D	D	D	D	D	D	D							

D= Day off
T= Working Day

1.5.5. Avionics Technician

The citizen See reference 2, of the nationality: See reference 2, holds a Class II Maintenance Technician License, valid as of October 06, 2021, has Electronics System capability.

He has an APT psycho-physical fitness certificate, valid as of February 05, 2021, without any observation or restriction from the examining physician.

In August 2015, he accredited the periodic course for aircraft maintenance technician on Agusta A109 E/S/SP SERIES equipment; in April 2018, he took the initial course of Maintenance in Electronic/Electronic Systems of the Agusta A109 Series helicopter.

This technician performed the two fault isolations on the SAS2 roll linear actuators in both July 2018 and December 2018.

Thirty days before the accident, he had this work shifts, available 24 hours a day.

	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
October	D	D	D	D	D	D	D	D	D	D	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T
November	D	D	D	D	D	D	D	D	D	D	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	
December	D	D	D	D	D	D	D	D	D	D	T	T	T	T	T	T	T	T	T	T	T	T	T	T							

D= Day off
T= Working Day

1.5.6. Maintenance Technician.

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The citizen See reference 2, of the nationality: See reference 2 holds a Class I Maintenance Technician License, valid as of December 15, 2019, and helicopters capabilities.

He has an APT psycho-physical fitness certificate, valid as of December 10, 2020, without any observation or restriction from the examining physician. In August 2018, he accredited the periodic course for aircraft maintenance technician on Agusta A109S and he took the previous course on this equipment in September 2016.

This technician performed the removal and subsequent installation of the MVA component.

Thirty days before the accident I had these work shifts, available 24 hours a day.

	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
October	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	D	D	D	D	D	D	D	D	D	D
November	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	D	D	D	D	D	D	D	D	D	D
December	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	D	D	D	D							

D= Day off
T= Working Day

1.6. Helicopter information.
1.6.1. General information.
The Agusta helicopter, model A109S, registration number XA-BON, year of manufacture 2010, had the Airworthiness Certificate number 20181252, issued on September 21, 2018, by the Aeronautical Authority of the International Airport of Puebla, with expiration on September 19, 2020 and with base of operations at the International Airport of Puebla; its configuration was of 08 seats (01 pilot + 01 co-pilot + 06 passengers), of Servicios Aereos del Altiplano, S. A. de C. V. It also had the equipment on board to perform operations by instruments (IFR) and authorization to perform night visual operations; it had two Pratt & Whitney PW207C turboshaft engines installed, which provided a power of 562 SHP each.

According to the historical movements recorded in the database of the Mexican Aeronautical Registry (RAM) DGAC (AFAC)/SCT, on August 30, 2011 this helicopter was issued the airworthiness certificate, being granted a provisional registration for 60 days, this being the XA-UDP, when it had 10:05 total flight hours and the holder was Eolo Plus, S. A. de C. V.; subsequently, on July 07, 2016, it requested a change of registration and was assigned a provisional registration for 30 days, being assigned the registration XA-BON; the last administrative movement was recorded on August 9, 2016, when it was assigned the registration number XA-BON and passed inspection due to change of ownership Servicios Aereos del Altiplano, S. A. de C. V., with its base of operation at the International Airport of Puebla. The helicopter had 1,284.24 total hours.

In the bank of accidents, serious incidents or incidents, of the Aviation Accident and Incident Analysis Directorate of the AFAC, this helicopter has no record of any type of event prior to the one under investigation.

According to the controls provided by the Rotor Flight Services, S. de R L. de C. V. (RFS)[15] workshop, the helicopter had the following times, updated as of December 23, 2018:

Component	Brand	Model	Series	Hours	Cycles
Basic body	Agusta	AW109S	22174	2,178.7	8,629.0
Motor 1	Pratt & Whitney	PW207C	See reference 3	2,178.7	9,531.0
Motor 2	Pratt & Whitney	PW207C		1,936.4	2,610.0
Core Main rotor	Agusta	109-0112-02-103		2,178.7	Not applicable
Tail rotor core	Agusta	109-0162-01-107		2,178.7	Not applicable

The checks of airworthiness directives, manufacturer's service bulletins, time-limited components and scheduled services provided by Rotor Flight Services, S.A. de R.L. de CV. were based on the times established by the manufacturer in their manuals.

There were no alterations (STC[16]) on this helicopter, which would modify the type certificate (TC[17]).

1.6.2. Helicopter maintenance history.

Considering that the XA-BON last two flight logs were destroyed by fire, the group of investigators, from the beginning of its activities, obtained from the aircraft operator and the aeronautical workshop, the following information related to the helicopter services:

1. Copies of the original log sheets, (those in possession of the RFS aeronautical workshop and SAA operator) from folio 001 to folio 950, green/blue sheets of the flight log, which cover the period from July 11, 2016 to October 8, 2018.
2. From folio 951 to folio 1063, images of photographs of the flight log sheets (those in possession of the operations area) were reviewed; from October 09, 2018 to December 23, 2018, these images cover only the front side (front), the back side (maintenance sheets) was not available.
3. Discrepancies forms from folio 01/2017 to 40/2017 and folio 01/2018 to 22/2018.
4. Work orders from No. RFS-175/2016 to No. RFS-251/2016; from No. RFS-002/2017 to No. RFS267/2017 and from No. RFS-006/2018 to No. RFS-462/2018; without continuous numbering, for having been issued as they were required for the XA-BON.

The last two XA-BON flight and maintenance logs were on board the aircraft at the time of the accident and were destroyed by fire; from the other maintenance records analyzed, it was observed that, occasionally, RFS aeronautical technical personnel did not record the required data and/or information in this regard, that is

- Work order information was not complete.
- The service release tags, in the maintenance log, did not contain all the component information.
- In work order RFS-0239/2016, the boroscopic inspection was performed by an external workshop, but the work order does not include the result of the inspection.

[15] In the AOC of Servicios Aereos Especializados, S. A. de C. V., it is established that the DGAC 371 Rotor Flight Services S. de R. L. de C.V., based at the Toluca airport, will provide maintenance services for both the engine and the basic body.
[16] STC, Supplemental Type Certificate
[17] TC, Type Certificate

- The label dated January 05, 2017 of the maintenance log does not refer to work order RFS-002/2017, nor does it specify the technical data of the repaired engine, nor does it contain all the component information.
- Work was performed that starts with the opening of a discrepancy, however, it takes a long time to close it, as in the case of discrepancy formats 21/2018 and 30/2018, which are related to the roll linear actuator of SAS2.
- On the two occasions that the RFS aeronautical workshop technicians removed the roll actuator from the Stability Augmentation System (SAS) there is no evidence in the logbook that they deferred per Minimum Equipment List (MEL) to the helicopter.
- In the discrepancy forms 21/2018 and 30/2018 they did not specify which roll actuator was removed and which one was installed.

The most relevant observations are recorded in Attachment A, item 4. Findings in the maintenance records.

The following technical defects[18] were detected in the information reviewed:

1.6.2.1. Electromechanical linear actuators.

The air operator Servicios Aereos del Altiplano entered into a contract for the RFS aeronautical workshop to provide:

> ***"Operation, Application of the Maintenance Program, application of Directives and Technical Bulletins, the correction of discrepancies, Pre-flight and Post-flight Inspection and Administration" [sic].***

Since August 1, 2016, the aeronautical workshop RFS was in charge of the maintenance of the XA-BON; the experts of the Colegio de Ingenieros Mexicanos en Aeronautica, A.C. and investigators of the DGAC (AFAC), analyzed all the available maintenance records of the helicopter, finding the following:

Based on the maintenance records available, it was detected that when the helicopter was assigned the registration XA-UPD, it had a total time of 74.1 hours; RFS replaced the Yaw Electromechanical Linear Actuator N/P 4012373-905 N/S See 3 443 with N/S See 3 250, recorded in the helicopter's blue book component removal and installation control sheets.

On September 08, 2017, RFS aeronautical workshop maintenance personnel generate discrepancy No. 28/2017, when the helicopter had 1,668:13 hours; in the discrepancy description section they stated:

> "***BY FLIGHT REPORT (IT PRESENTS ABRUPT MOVEMENTS IN THE ROLL AXIS DURING ITS STRAIGHT AND LEVEL FLIGHT) BY REMOVING THE SWITCH OF THE S.A.S. NO. 2 THIS MOVEMENT IS REMOVED. THE SYSTEM WAS INSPECTED AND FOUND TO BE VERTICAL ROTATION NO. 2 DAMAGED. IT REQUIRES REPLACEMENT." [sic]***

However, in the corrective action they indicated: ***"Cancelled is generated disc. 30/2017" [sic].***, It should be noted that the flight and maintenance log (folio 421) was reviewed and there were no observations or reports recorded by the crew in this regard.

[18] OACI defines a defect as damage (structural failure that adversely alters its structural strength characteristics, performance or flight characteristics, and would normally require major repair or replacement of the damaged component) that affects the airworthiness of an aircraft or component thereof.

It should be noted that in the discrepancy form 28/2017 the maintenance area initially isolated the failure in the vertical turn number two and after an additional report from the crew (after 10 days), the technicians perform again the evaluation of the failure, following the procedure of the Maintenance Manual No. 0B-A-22-11-00-00A-340A-A, closing the discrepancy form 28/2017 and generating a new discrepancy form No. 030/2017, isolating this time the failure in the roll linear actuator of the SAS2 which is described below:

On September 18, 2017, the maintenance area generated discrepancy 030/2017, when the helicopter had 1,677:47 hours, for:

> ***"(...) BY FLIGHT REPORT. AIRCRAFT DEVIATES FROM COURSE TO THE LEFT OCCASIONALLY WITH FLIGHT DIRECTOR ENGAGED. OPERATIONAL TESTS WERE PERFORMED ACCORDING TO MM REF 0BA-22-11-00-00A-340A-A, AND A LINEAR ACTUATOR OF THE ROLL SHAFT WAS FOUND TO BE DAMAGED. IT REQUIRES REPLACEMENT (…)" [sic]***

Removed the **N/S** See 3 **506** roll linear actuator from the SAS2 and installed the **N/S** See 3 **118**, leaving the helicopter airworthy; the discrepancy was closed on October 19, 2017 when the helicopter had 1,719:32 hours, flying 41.7 hours, elapsing 31 days. For this replacement, there is no record in the maintenance log that the maintenance technicians have deferred SAS2 for MEL. It should be noted that the flight and maintenance log (folio 434) was reviewed and there is no observation or report recorded by the crew in this regard.

The Aeronautical Workshop Rotor Flight Services, S. A. de C. V., purchased the actuator **N/S** See 3 **118** from Precision Aviation Group Inc. in repaired condition (Overhaul), having as support the FAA form 8130- 3, number 2200748, dated April 27, 2017.

The maintenance log folio 0785 (see image 2, Attachment A) shows that on June 25, 2018, the XA-BON crew noted:

> ***"(...) SUDDEN CHANGE OF COURSE WITH CRIMPED FLIGHT DIRECTOR (...)" [sic]***

The technical personnel (an inspector and an avionics technician) of the RFS workshop will perform the corresponding troubleshooting, indicating the following in the logbook:

> ***"(...) Flight director system inspection performed and discrepancy generated 09/2018 requesting electric actuator[19] (…)" [sic]***

For which discrepancy forms number 09/2018 were generated (see image 3, Attachment A) where it describes:

> ***"(...) BY FLIGHT REPORT THE AIRCRAFT DEVIATES FROM COURSE TO THE RIGHT OCCASIONALLY WITH THE FLIGHT DIRECTOR CRIMPED. OPERATIONAL TESTS WERE CARRIED OUT ACCORDING TO MM REF 0B-A-22-11-00-00A-340A-A. FOUND A ROLL SHAFT LINEAR ACTUATOR TO BE DAMAGED. IT REQUIRES REPLACEMENT (...)" [sic],***

[19] The electric actuator refers to the electromechanical linear actuator.

JACT / ... / MAHG / ESM / MAHP
[Illegible Signatures]

It should be noted that the helicopter continues to operate without the technical staff of the RFS aeronautical workshop recording in the maintenance log the ATA 22 Auto Flight, 1 Stability Augmentation System (SAS2), category B, in the DIFFERENCES UNDER MEL[20] section.

The records analyzed show that the helicopter operated without reports involving SAS2 functionality, until July 4, 2018, when it had 1,978:36 hours, flying 13.9 hours with the SAS2 roll actuator **N/S** See 3 **118**; on this date the SAA representative and RFS agree on the removal of the SAS2 roll actuator **N/S** See 3 **118** and install the SAS2 roll actuator **N/S** See 3 **551**, which was turned on loan from the helicopter XA-AYH, model A109S.

The roll actuator **N/S** See 3 **118** of the removed SAS2 was sent for repair to the Precision Accessories& Instruments (PHP-PAL) workshop, the workshop generated the FAA 8130-3 format dated August 30, 2018, certifying that said component was ready to be used again, after performing the major repair (Overhaul). In this period the XA-BON continues to operate until reaching 84.5 hours (from July 4, 2018 to September 10, 2018), with the roll actuator **S/N** See 3 **551** of the SAS2 on loan, the technicians indicated in the interview to the investigators that in this period they had no reports of sudden change in heading, which is confirmed in the log sheets of those dates, also noting that they did not receive any verbal or written report, in this regard, from the crew of the XA-BON.

On September 10, 2018, the technical staff of the RFS workshop received the roll linear actuator **N/S** See 3 **118** of the SAS2, which had been sent for repair to the PHP-PAL workshop, proceeding to install it on the helicopter, closing discrepancy number 09/2018 dated June 26, 2018, when the helicopter had 2,063:02 hours.

On December 13, 2018, technicians (an inspector and an avionics technician) generated discrepancy 21/2018; to the best knowledge of the RFS technicians, the XA-BON crew reported in the maintenance log that: **"*there was an in-flight deviation*"**, however, the back of log sheet 1043 was not recovered (see point 1.6.2. of this document). On this date the helicopter had 2,165:02 hours.

In the discrepancy format 21/2018 it was stated:

> ***"(...) PER LOGBOOK REPORT FOLIO 1043 AND WHEN PERFORMING OPERATION TESTS ACCORDING TO MM REF. 0B-A-22-11-00-00A-340A-A. THE ROLL LINEAR ACTUATOR WAS FOUND DAMAGED. IT REQUIRES REPLACEMENT (...)" [sic]***

In the remarks section of the document, the following is stated:

> ***"(...) SAID ACTUATOR WAS INSTALLED ON SEPTEMBER 10, 2018 WITH T.T A/C: 2063:02 HRS IN REPAIRED CONDITION. IT HAS ONLY OPERATED. 102 HRS (...)" [sic]***

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[20] According to the MEL of Servicios Aereos del Altiplano, S. A. de C. V., the 22 Auto flight, 1 Stability Augmentation System (SAS), has a repair category B, which indicates that it will be repaired within three (3) consecutive calendar days (72 hours), excluding the day the malfunction was recorded in the logbook; it should be noted that there is no extension in the number of days, the MEL also indicates that either SAS1 or SAS2 may be inoperative within the three days, provided that the limitations established in the Flight Manual are met or the other condition is that both systems (SAS1 and SAS2) may be inoperative within the three days provided that the flight is conducted under visual flight rules and that SAS1, SAS2 and ATT HOLD are not activated, and that the limitations established in the helicopter's Flight Manual are met.

In the interview with the technical personnel who performed this work, it was stated that they carried out the isolation of the corresponding failure, finding the roll actuator **N/S** See 3 **118** of SAS2 damaged and stating that it required replacement.

It should be noted that the helicopter continued to operate without the technicians having recorded in the maintenance log that the ATA 22 Auto Flight, 1 Stability Augmentation System (SAS2), category B was deferred by the air operator's MEL.

The technicians used the operator's MEL as a basis and, consequently, did not apply the Master Minimum Equipment List (MMEL) rev. "E" procedure, which indicates that the maintenance area (M) should place an out-of-service (F/S) card and ensure that SAS2 is disabled. Remaining open discrepancy format (21/2018).

The replacement of the **N/S** **See 3** **118** roll linear actuator of the SAS2 should have been performed prior to December 17, 2018, in accordance with SAA's MEL which limited to 3 days without extension to change the component, once the failure is detected. If the air operator had implemented MMEL revision "E", the ATA 22 Auto Flight, 1 Stability Augmentation System (SAS2), category C, replacement of the SAS2 roll linear actuator should have been performed no later than December 23, 2018.

1.6.2.1.1. SAA Minimum Equipment List (MEL).
The Minimum Equipment List (MEL) is a document based on the Master Minimum Equipment List (MMEL) which provides for the operation of the aircraft under specific conditions, when certain systems, equipment or components are not operational at the start of the flight and for which the aircraft may be dispatched, provided that the operational procedures (O) and/or maintenance procedures (M) that may be associated with each of them are observed. It also indicates that when an item is detected as inoperative, it must be reported by making an entry in the aircraft logbook; when this happens, the item may be repaired or deferred by MEL. This document is prepared by the operator for each of its aircraft and is approved by the aeronautical authority.

On February 24, 2017, SAA requested to the DGAC the authorization of reedition 1, to the Minimum Equipment List (MEL) applicable to the XA-BON helicopter, according to the information contained in the MMEL Revision D, dated December 10, 2015, which applied for being the recent revision, where the following restrictions to section 22 Auto Flight were settled (see image 1.6.2.1.1.1.1).

SAASA
SERVICIOS AEREOS DEL ALTIPLANO, S.A. DE C.V.
HANGAR D-5 AEROPUERTO INTERNACIONAL DE PUEBLA C.P. 74160
HUEJOTZINGO PUEBLA

AIRCRAFT: A109S SERIAL NUMBER: 22174 REGISTER: XA-BON

1. SYSTEM, SEQUENCE NUMBERS & ITEM	REPAIR CATEGORY	2. NUMBER INSTALLED	3. NUMBER REQUIRED FOR DISPATCH	4. REMARKS AND EXCEPTIONS
22 AUTO FLIGHT				
1 Stability Augmentation System (SAS)	B	2	1	One may be inoperative for VFR, provided RFM limitations are complied with.
	C	2	0	Both may be inoperative provided the flight is conducted under VFR, and SAS1, SAS2 and ATT HOLD are not engaged
2 Attitude Hold	C	1	0	May be inoperative for VFR, provided procedures are not depending on its use

1.6.2.1.1.1 MEL developed by the Altiplano, based on the MMEL revision D

On March 08, 2017, the DGAC authorized the air operator the content of re-edition 1, to the Minimum Equipment List Manual based on the MMEL Edition D, of December 2015, applicable to the XA-BON

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helicopter, which adhered in its total content to the MMEL published by the European Aviation Safety Authority (EASA), where there was a restriction of repair level "B" of an inoperative SAS of 3 days, with no extension in the number of days.

1.6.2.1.2. Master Minimum Equipment List (MMEL).

The function of the MMEL is to determine which system, equipment or component may be temporarily inoperative within the aircraft, however, the level of safety is maintained. This document is prepared by the organization responsible for the design of an aircraft and approved by the aeronautical authority of the State of Design.

EASA published the MMEL Revision E, in May 2018, where the system 22 Autoflight, Stability Augmentation System, affects the level of repair of an inoperative SAS to a category "C", this category has contemplated a period of 10 days to perform the replacement of the component excluding the day in which the finding was made.

Also in the MMEL Revision. E, the person responsible for performing this activity was recorded, in this case it appears with an ***"(M)"*** which indicates that a specific procedure is required from the Maintenance area, which must be performed before the operation of the helicopter with the list of the systems that are inoperative.

Satisfactory performance of all maintenance procedures, regardless of who performs them, is the responsibility of the operator.

Appropriate procedures should be published as part of the operator's General Operating Manual or MEL. Note: The ***"(M)"*** symbols are required to be marked on the operator's MEL.

Aircraft	Revision No:	E	Page
A109S	Date	XX/02/2018	22-1

(1)	System & Sequence Numbers Item	(2) Rectification Interval	(3) Number Installed	(4) Number required for dispatch	(5) Remarks or Exceptions
22	AUTOFLIGHT				
-1	Stability Augmentation System (SAS)	C	2	1	(M) One SAS may be inoperative provided that: - The inoperative SAS is deactivated and secured, AND - VFR operations only are conducted, AND - All the RFM limitations for VFR operations only and applicable in case of failure/loss of one SAS during flight, including the relevant Airspeed Limitation referenced therein, are complied with Note: Following loss of one SAS, the autorim function is inoperative
	Applicable to A109S Basic only	C	2	0	(M) Both SAS may be inoperative provided that: - Both SAS are deactivated and secured, AND - VFR operations only are conducted, AND - SAS1, SAS2 and ATT HOLD modes are not engaged Note: Following loss of both SAS, FD Modes are not available

1.6.2.1.2.1. MMEL Revision E, approved by EASA on May 17, 2018.

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The MMEL Revision E, in the Remarks section ***"(5) Remarks or Exceptions"***, has two very important notes stated by EASA: the first one states that a SAS may be inoperative ***"(M) One SAS may be inoperative provided that:",*** however, it indicates that the inoperative SAS must be deactivated and

secured ***"The inoperative SAS is deactivated and secured[21], AND"***, finally there is a note that states that when a SAS is inoperative the **AUTOTRIM** is inoperative ***"Note: Following loss of one SAS, the autotrim function is inoperative".***

In the event that both SAS are inoperative ***"(M) Both SAS may be inoperative provided that:"***, they must be deactivated and secured ***"Both SAS are deactivated and secured, AND"***, there is a note indicating that when this happens the pilot will not have **FD**[22] ***"Note: Following loss of both SAS, FD Modes are not available"***. In addition to adhering to all limitations established in the helicopter flight Manual for visual flight operations and those that apply in the event of SAS failure during flight, including speed and altitude.

From the above, it is necessary to highlight that on December 13, 2018, RFS technicians (an inspector and an avionics technician) detected that the SAS2 roll actuator required replacement because the actuator was not performing its function correctly, which was recorded in discrepancy 21/2018 (December 13, 2018).

1.6.2.2. Rotary scissors.
It was detected in the maintenance records that several works and changes were made to the rotary scissors, which are listed below:

Date	Total time	Technical Reference	Reason for replacement	Series removed	Series installed	Condition
Jul-25-11	166.4	N/T	Replaced the complete rotary scissor assembly for out-of-limit play.	See reference 3		Repaired
Nov-14-11	281.0	31/2011	Replaced the complete rotary scissor assembly for out-of-limit play.	See reference 3 [redacted]		Repaired
Sep-01-12	530.3	25/2012	Replaced the complete rotary scissor assembly for out-of-limit play.	[redacted]		Repaired
Jan-24-14	793.9	35/2013	Replaced the complete rotary scissor assembly for out-of-limit play.	[redacted]		Repaired
Dec-20-18*	2,176.5	20/2018	Replaced lower rotating half scissors for out-of-limit play.	[redacted]		Repaired

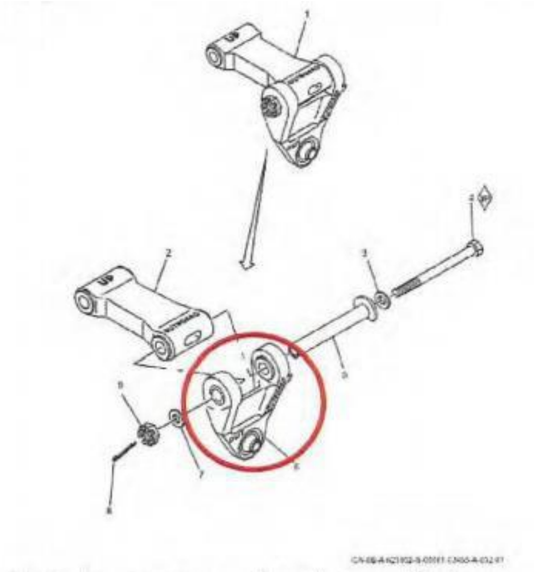
*Note: The label and the discrepancy format, for the installation of the half scissor See 3 to N/S M1059, have the same date, but not the same discrepancy number, although they do correspond to the referred work (play in the spherical bearing and bushings, detected during the daily verification)[23]; in interview with the RFS workshop maintenance technical staff, he clarified that due to a typing error, they left the discrepancy number 035/2077 dated October 19, 2017, but the real one was 020/2018

[21] The manufacturer established in point 7 "Guidelines for (M) procedures" of the MMEL, that the deactivation of the system is performed by removing the breaker from the corresponding circuit and securing the system by locking the corresponding breaker through a ring-plug and a tag.
[22] Flight Director
[23] The scheduled inspection to verify the set, is performed every 100 flight hours (OT: RFS-337/2018), the last inspection was performed on October 12, 2018, when the helicopter had 2,101 flight hours.

dated December 04, 2018. In fact, the last discrepancy in December 2018 was 022/2018, to change coals of a gear-generator.

In this task, maintenance personnel removed 4 bushings (N/P 07-261-08-024), 2 shims (N/P 120-008C34E21), 1 rotary half scissor assy (N/P 109-0134-10-705), 1 sleeve (N/P 109-0110-69-107) and 1 sleeve (P/N 109-0110-69-105); these same components were installed as new, except for the rotary half-scissor which had a repaired condition, with its respective FAA Form 8130-3.

1.6.2.1. Half scissor removed on December 20, 2018 for excessive spherical bearing play.



1.6.2.2. Image provided by the manufacturer of the removed part for further exemplification.

1.6.2.3. Starter generator and carbons replacements.

Date	Total time	Technical Reference	Reason for replacement	Series removed	Series installed	Condition
Jun-19-18	1,958:25	Major repair	Replacement of starter generator #1 N/P 160SG139Q-2.	See reference 3 [redacted]	[redacted]	Major Repair
Jul-27-18	1,998:14	10/2018	Replacement of starter-generator #1 N/P 160SG139Q-2 for maintenance agreement.	[redacted]	[redacted]	Major Repair
Aug-31-18	2,050:47	241/2018	Special inspection every 300 hrs of the starter-generator (the owner requested an inspection every 50 hours). At this time, all brushes were replaced. Bill of Materials IAW Work Order N/P 150SG1009-20XL2	N/A	N/A	New

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Date	Total time	Technical Reference	Reason for replacement	Series removed	Series installed	Condition
Oct-12-18	2,101:08	337/2018	Special inspection every 300 hrs of the starter-generator (the owner requested an inspection every 50 hours). At this time, all brushes were replaced. Bill of Materials IAW Work Order N/P 150SG1009-20XL2	N/A	N/A	New
Dec-13-18	2,165:02	22/2018	At the 300 hr inspection of both starter-generators the carbons were found to be damaged and were replaced IAW MM @A/C TT: 2,168:32hrs.	N/A	N/A	New

1.6.2.4. Generator Control Unit Replacements

Date	Total time	Technical Reference	Reason for replacement	Series removed	Series installed	Condition
Ju-27-18	1,998:14	08/2018	Start failure on engine #1 after troubleshooting the Generator Control Unit (GCU) #1 was replaced.	See reference 3		Repaired
Aug-19-18	2,021:12	12/2018	The starter generator #7 failed and the electrical bus side #1 was disconnected, the system could not be reset. After fault isolation the GCU #1 was replaced.	[redacted]	[redacted]	Repaired
Sep-07-18	2,059:11	15/2018	For maintenance purposes, GCU #1 N/P GCSGS0S-28-1 was replaced.	[redacted]	[redacted]	Repaired

1.6.2.5. Changes of other components.

In the review of the maintenance records the following was found[24]:

1. On October 17, 2017, the swashplate support (swashplate support N/P 109-0110-05-101) was replaced with a different part number (N/P 109-0134-29-101), the latter made of steel instead of aluminum; as a result, it has a new life limit of 24,000 flight hours. This is a modification that the manufacturer approved to RFS.
2. The Mast Vibration Absorber (MVA), which, in turn, contained the Mass Vibration Absorber (MVA), according to the maintenance history, was installed on the helicopter.
3. The MVA (mast vibration absorber) was removed on July 22, 2018 when the helicopter had 1,994.13 flight hours (Work Order RFS-215/2017, dated October 17, 2017, work order closing date was July 22, 2018)[25], when the swashplate mount was replaced to have reached the 1,000 flight

[24] The equipment list and installed/removed component lists show a number of inconsistencies, some of which are associated with, but not limited to, the recurring failures mentioned above. In several cases, the EASA Form 1 or FAA 8130 is also missing.
[25] As of July 27, 2018, some of these actions of the installed teams were recorded without stamp and/or signature.

hour life Limit. It should be noted that this component was scheduled to be replaced at 2,000 flight hours.

4. From the Optional Bulletin A109S-32, which describes the installation of the MVA (mast vibration absorber) the Work Order (TO) RFS-298/2018 is generated, so technicians of the RFS aeronautical workshop checked the torque of the MVA (reference 0B-A-05- 70-13-00A-000A-A) for 5-10 hours of flight, also checking the nuts of the main rotor ring nut bolts when the helicopter had 2004:42 hrs, August 3, 2018.

1.6.2.6. Engines.

a. On April 06, 2018, the crew recorded on folio 674 of the maintenance log in the Observations and Reports section:
"(...) Presented the engine 1 compressor stall during the transition from idle to flight, 3 continuous pops (...)" (sic].

Maintenance indicated:
"(...) Revised according to M. M. Ref. 72-00-02, fig-114, becoming operative. (...)" [sic].

b. On April 12, 2018, the crew recorded on folio 677 of the maintenance log in the Observations and Reports section:
"(...) Presented the engine 1 compressor stall during the transition from idle to flight, 2 continuous pops (...)" (sic].

Maintenance indicated:
"(...) The compressor was washed with solution and the compressor blades were checked, ground tests were carried out and no anomalies were found. (...)" [sic].

c. On April 23, 2018, the crew recorded on folio 686 of the maintenance log in the Observations and Reports section:
"(...) 1. Presented the engine 1 compressor stall during the transition from idle to flight, 5 pops, 2. Engine 2 start was not effective (no start) (...)" [sic]

Maintenance indicated:
"(...) 1. The compressor of both engines ref. 72-00-02, 2 was washed and operational tests were carried out (...)" (sic].

The engines received the 200 hour service, carried out as of November 28, 2018, i.e. they had 28.10 hours from their last inspection. The "pops" and slumps on engine number one may be an indication of fouling of the internal engine components due to insufficient compressor flushing, this can be confirmed by the maintenance action of flushing this module. After the compressor was washed out, checks performed indicated that the engine regained power margin and returned to normal operation with the scheduled plan. There were no further reports recorded in maintenance log in this regard after April 23, 2018.

Regarding the history of inspections and maintenance performed on the engines, only engine position 1, with a total time of 2,178.7 hours, had the following discrepancies:

a. The monitoring of parameters carried out, especially the power verification, were not duly recorded in the logbook.
b. Application of borescope inspection every 50 hours (manufacturer's recommendation P&WC).

c. When the engine reaches a total time of 1,600 hours, it requires a hot section inspection (HSI). P&WC had agreed that the engine could be considered "on-condition" and delay the HSI, as long as the performance margin remained positive, in June 2018, the workshop complied with the intermediate inspection, when this engine had 1,952 total hours.

Following the field investigation, an initial evaluation was conducted and the engines were sent for further investigation. See item 1.15.3 of this factual report for information on the initial inspection at the accident site.

1.6.3. Operational data.
According to the Type Certificate (TC) database number EASA.R.005 issued by the European Aviation Authority (EASA), the holder of the TC is Leonardo S.P.A, the helicopter is Category A, Small Rotorcraft, approved on June 1, 2005; among other information contained in the TC are the following most representative operational data:

Maximum take-off weight:	3,175 kg
Number of fuel tanks:	2
Fuel capacity:	563 lt
Maximum speed:	311 km/hr (168 knots)

No. of Crew:	1 pilot
No. Passengers:	7
Roof:	6,096 m (20,000 feet)

1.6.4. Load and balance.
According to the referral dated December 24, 2018, the helicopter was supplied with the amount of 286 liters (225 kgs) of turbosine and considering the data that have been investigated, it was determined that one passenger was in the middle seat and two in the rear seat, with no luggage in the cargo compartment, so the Takeoff Weight (PD) was 2,915.0 Kgs and the center of gravity (CG) was 3,307.0 mm from Datum; concluding that the CG was within the flight envelope.

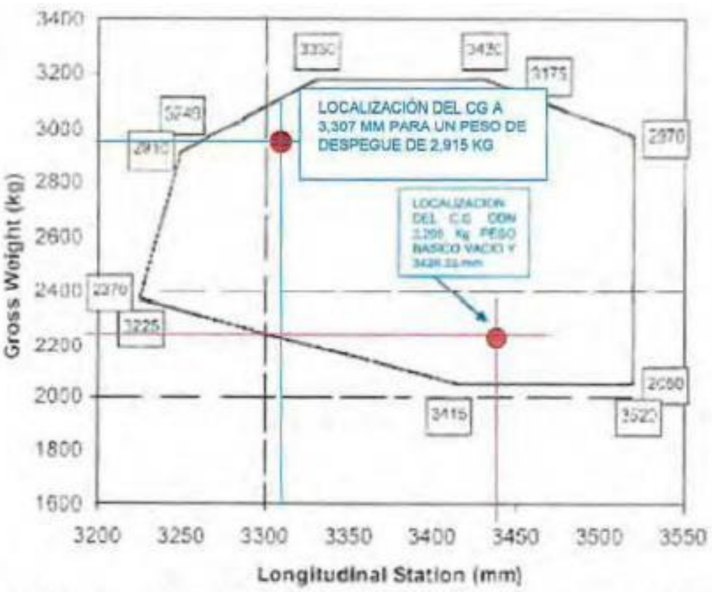
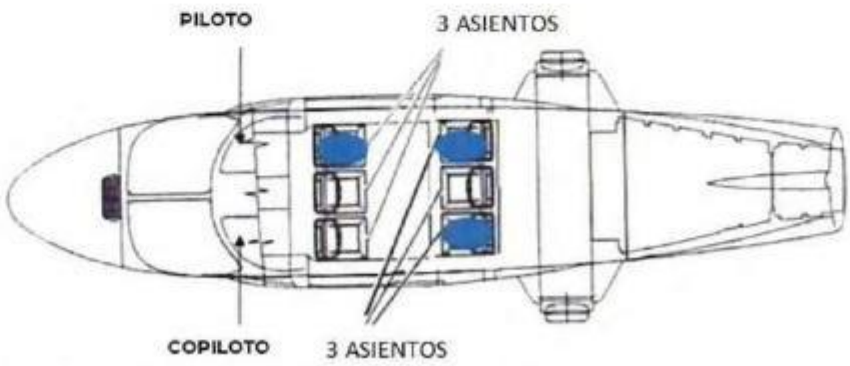


Fig. 1.6.4.1. CG enveloping with an empty weight and a take-off weight of 2,915 kg



Considering the weather conditions and the operation data of the XA-BON helicopter mentioned above, with a cruise altitude of 2,895.6 m (9,500 ft.) proposed by the crew and corroborated by the radio altimeter reading, the ambient temperature of 21°C, obtained from METAR, according to graph 1-5 of the A109S Flight Manual, an equivalent altitude density of 3,810 m (12,500 ft) is obtained, to have a never exceed speed (Vne) of 154 knots.

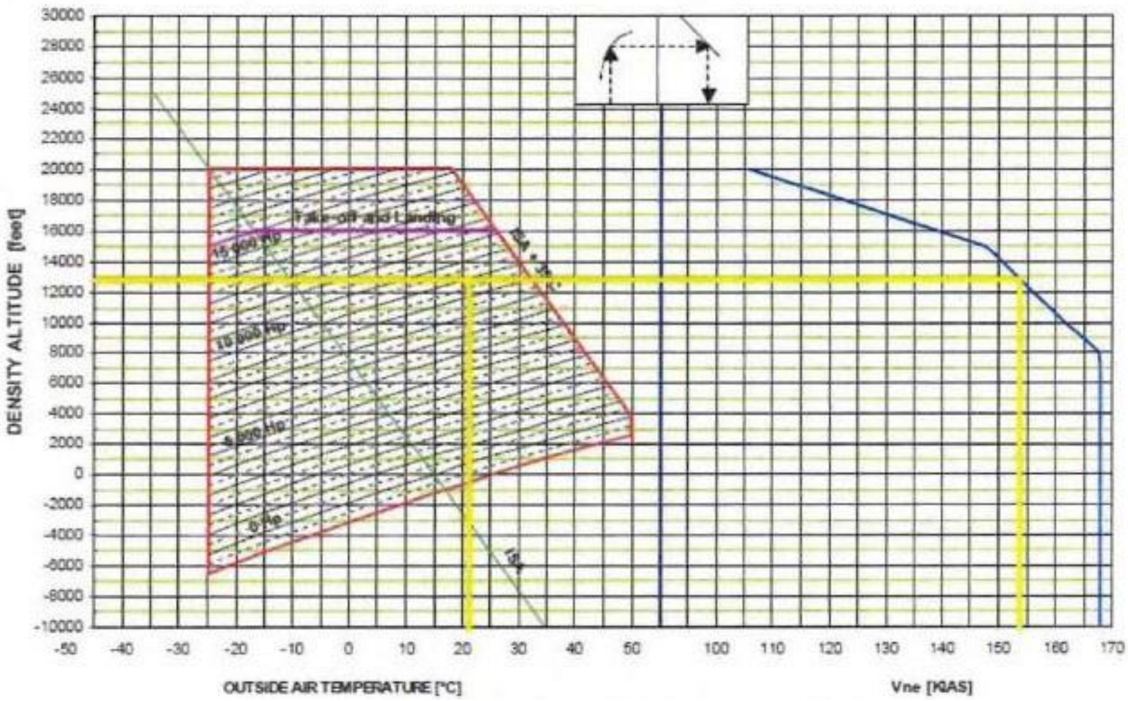


Fig. 1.6.4.3. Graphic 1-5 Airspeed limitation Vne (Power-Gn)

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1.6.5. Loss of control in flight (LOC-I[26]).

Based on the evidence obtained from the field investigation, maintenance history, after analyzing the mechanics of the impact and fire and assessing witness statements, it was concluded that it was possible to investigate 6 possible scenarios that could have caused a loss of control in flight related to a mechanical failure.

The methodology to determine which of the 6 scenarios proposed were involved in the accident consisted of inspecting all the available mechanical components that involve the systems inherent to the scenarios mentioned below, as well as their components.

1. Failure to transmit power to the main rotor head.
2. Failure to transmit power to the tail rotor head.
3. Failure to provide lift to the rotorcraft.
4. Failure to provide anti-torque thrust.
5. **Both linear actuators driven in simultaneous hardover in pitch or roll axis.**
6. Loss of hydraulic power in both flight control circuits.

The results of the analysis of these components are included in Exhibit D. "Inspection of flight controls". Upon inspection of the components of each of the systems involved, as described above, the evidence of the damage they presented indicated overexertion, impact damage and fire, so it was determined that the systems examined were not involved in the occurrence of the accident; except for those indicated in scenario number 5 "Both linear actuators driven hard-over in pitch/roll axis", due to the evidence gathered in the field investigation, laboratory data, analysis of technical maintenance information and because there was a component that needed to be changed and was not done. For this reason, the investigation focused on the helicopter's automatic flight system, with special interest in the electromechanical linear actuators, since the rest of the components (Helipilot computers and vertical gyros) of the autopilot system were destroyed by impact and fire."

1.6.6. Description of the Automatic Flight System (AFCS).

The Automatic Flight Control System (AFCS) performs the basic stabilization and autopilot (AP) functions of the helicopter. The AFCS includes:

a. The Automatic Stabilization Sub-System.
b. The auto-trim sub-system.

The AFCS works in conjunction with the attitude and steering System, the yaw rate turn System and the flight director System and are the means to automatically control the flight. The schematic diagram of the AFCS is shown in Attachment A, Figure 4.

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[26] It refers to accidents in which the flight crew was unable to maintain control of the aircraft in flight, resulting in an unrecoverable flight deviation. LOC-I can result from a variety of scenarios including engine failure, icing or deplaning.

The AFCS consists of two independent subsystems controlled by a common control panel. Each system consists of a computer, three linear actuators for SAS 1, two linear actuators for SAS 2 and two synchro-transmitters of positions (pitch and yaw); the linear actuators are interconnected, through the mixer unit, with the hydraulic servo-actuators of the cyclic stick, from here they are connected to the swash plate and from this the pitch change rods which, in turn, are connected to the main rotor blades; the yaw linear actuator is connected to the hydraulic servo-actuator of the tail rotor; the yaw linear actuator is connected to the hydraulic servo-actuator of the tail rotor.

Computer No.1 processes the attitude and heading signals from the vertical gyro and yaw rate gyro and the signals from the synchro-transmitters position from the cyclic stick and rudder pedals; it then sends the correct control signals to the linear actuators. Computer No. 2 works in the same way as computer No. 1, but without the yaw channel.

The displacement stroke of the linear actuators longitudinally is of the order of 5.28% (with respect to the total stroke control) and the displacement of the linear actuators laterally is of the order of 5.34%; while the displacement of the yaw linear actuator is of the order of 7.21%.

The linear actuators are installed in series in the linkage control and, therefore, operate without changing the position of the cyclic rod and pedals. Synchronous transmitters detect the rotation of the control to which they are connected by means of links. The nominal rotation of synchro-transmitters is ±30°.

The automatic stabilization system has two modes of operation:

- Stability Augmentation System (SAS) and
- Attitude hold mode (ATTD HOLD).

In SAS mode, each automatic stabilization channel functions as a damping system to stabilize the helicopter when its normal flight configuration is changed by external forces (turbulence, updrafts/downdrafts, and sudden heading changes). In this mode, the operation of the automatic stabilization system does not interfere with the helicopter attitude changes commanded by the pilot.

In ATT HOLD mode, each automatic stabilization channel is capable of maintaining the flight comfort attitude, providing the pilot with limited hands-off flying capabilities. The pilot has the possibility to momentarily control the helicopter by operating the beeper trim selector switch located on the cyclic stick grip.

To allow automatic control of the flight path, the automatic stabilization system (SAS) can be coupled to the flight director system. In this mode, the computers automatically steer the helicopter along the longitudinal and transverse axes, to follow the commands of the FD (Flight Director), which are displayed on the EADI (Electronic Attitude Display Indicator).

The operation of the automatic stabilization system is monitored through caution messages that appear on the pilot's EDU (Electronic Display Unit) when the system is not operational.

The main components of the system and their location are shown in Attachment A, Figure 5.

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When engaged, the Autotrim System provides power to the lateral and longitudinal cyclic magnetic brakes at any time when both pitch and roll linear actuators have exceeded 30% of their travel in the same direction (both in extension or both in retraction), and have been under this condition for at least 3 seconds for the Autotrim System to return to its center position. This action restores full authority to the actuators and relieves the pilot from continuous monitoring.

Note: Readjustment of the yaw axis is required. The auto-trim system is operative when both automatic stabilization systems are in COUPLED mode. The auto-trim action can be interrupted by disengaging either automatic stabilization system, by applying force to the cyclic stick or by turning the F-TRIM (Force Trim) switch to Off.

Graph of the main components of the Auto-trim System and their location are shown in Figure 6, Attachment A.

The A109S helicopter is equipped with a flight director (FD) system. This system processes navigation and attitude information by means of an external sensor and provides steering commands in the pitch and roll axes, which are displayed on the EADI and fed to the automatic stabilization system for automatic en-route flight control.

The FD system works in conjunction with the VOR/LOC, gyrocompass, vertical gyro, radio altimeter and automatic stabilization systems. It consists mainly of a computer, an altitude sensor, an airspeed sensor, a control panel, a collective lever synchro-transmitter. The FD computer provides all pitch, roll and collective axis commands to the EADI and the automatic stabilization system computer.

The side channel combines selected heading, attitude, navigation and course data entered into the cyclic side computer. Altitude, airspeed, instantaneous vertical speed, glide slope errors are calculated and combined with pitch attitude to provide longitudinal cyclic commands. Internal monitoring provides automatic retraction when a sensor does not send correct information or the computer has failed, thus preventing the pilot from following an invalid command. The altitude sensor uses static pressure, obtained from an integral static pressure port, to produce an output signal that is proportional to altitude. This output signal is used in the FD computer to provide information to maintain an altitude and vertical speed.

The air velocity sensor uses dynamic and static pressures to produce an output signal that is proportional to the calibrated air velocity. This output signal is used in the FD computer to provide information on the velocity to be maintained. The dynamic pressure is obtained from line No. 2 of the pitot tube, while the static pressure is obtained from an integral port that senses static pressure.

The FD control panel allows the pilot to select various flight modes of the system. The control panel has illuminated pushbutton switches to select the FD Standby, Bank axis or Pitch axis mode of operation. When an operating mode is selected, that mode is displayed by the illumination of the push-button switch. The synchro-transmitter provides collective lever position information for use in the FD computer in GA (Go Around) mode. The MSTR AVNX interrupter controls the circuit breakers. The main components of the FD System and their location are shown in Figures 7 and 8, Attachment A.

1.6.7. Flight controls.

Scenario 5 of the 6 related to loss of control in flight, has to do with both linear actuators activating simultaneously to a hardover[27] situation in the pitch or roll axis. This functional failure is critical when the operation is performed under instrument flight rules (IFR), at high-speed hands off flight, and is classified as catastrophic by LHD, due to a sudden uncommanded movement of the flight controls that may cause an abrupt change of attitude of the aircraft with possible loss of control. The following considerations should be taken into account:

1. The attitude signals are supplied to the two Helipilot computers, by means of two independent vertical gyroscopes. The two linear actuators, installed in series, are controlled independently by the two Helipilot computers (each Helipilot controls only one pitch and one roll linear actuator). Therefore, two independent failures can occur in the vertical gyroscopes, in the Helipilots or in the linear actuators.

2. This scenario is considered catastrophic only in the case of a double hardover, the direction of the hardover must be in the same direction, either both in extension or both in retraction, both in the pitch axis or both in the roll axis, independently and simultaneously during high speed IFR flight, as the pilot may not have sufficient time to react to the first hardover and keep the aircraft attitudes under control, if the second actuator failure occurs before the conventional reaction time of 3.5 seconds.

   In fact, hardover of a single linear actuator does not result in a catastrophic scenario.

   There are two corrective actions by the pilot in the event of loss of control of a helicopter, related to hardover, and they are:

   Action 1. *One linear actuator experiences a "hardover" and the second linear actuator compensates*. When the helicopter is in <u>flight phase</u> and a linear actuator ***extends/retracts*** to its extreme without being commanded, i.e. when a "hardover" occurs, the helicopter will present an almost imperceptible roll to the **left/right**, because this failure is immediately corrected by the linear actuator of the helipilot that is operative (SAS 1 or 2); the pilot, after taking the controls and turning off the linear actuator that presented the failure, should only restrict its operation to visual flight rules and that the flight is continued with a maximum speed of 128 knots and/or with a vertical speed of 1,000 ft/min, and minimum height above ground of 500 ft; being the helicopter fully controllable. (see 1.6.8.1.a.)

   Action 2. *One linear actuator experiences a "hardover" and the second actuator is out of service [OFF/no power].*
   When a helicopter is dispatched with an inoperative SAS (1 or 2), the applicable RFM limitations and MEL instructions apply. If a failure of the "remaining" operational linear actuator occurs, the helicopter will perform a roll to the left or right (depending on the direction of the hardover), the pilot may still regain control of the helicopter, after shutting down the second linear actuator, flight may continue with manual controls.

[27] Mechanical displacement, in the direction of extension or retraction, up to the limit of displacement or movement available without being commanded, remaining in that position.

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Hardover on a single linear or dual actuator (even simultaneous or occurring within 3.5 seconds of each other) in the same direction would not result in a catastrophic scenario if the pilot is manually flying the helicopter (manual control).

3. Therefore, to result in a catastrophic effect, the two linear actuators either on the roll axis or both on the pitch axis would have to move to the limit of their stroke (not commanded), both in the extension direction or both in the retraction direction, i.e. to "hardover" "simultaneously"[28] and must be attended (commanded) within a reaction time of 3.5 seconds to bring the flight into manual mode.

4. This scenario is considered catastrophic only in the case of a double hardover, the direction of the hardover must be in the same direction, either both in extension or both in retraction, both in the pitch axis or both in the roll axis, independently and simultaneously during high speed IFR flight, as the pilot may not have sufficient time to react to the first hardover and keep the aircraft attitudes under control, if the second actuator failure occurs before the conventional reaction time of 3.5 seconds.

1.6.8. Helicopter Operating Restrictions.
1.6.8.1. Helipilot operation.
The following considerations were taken from Section 1, Limitations of the A109S Helicopter Flight Manual (Doc N°109G0040A013).

When the helicopter is in flight and it is present that only one helipilot is operational (SAS 1 or SAS 2) the helicopter flight manual indicates that:

AUTOMATIC FLIGHT CONTROL SYSTEM LIMITATIONS

Minimum AFCS configuration
for VFR flight .... No helipilot (SAS/ATTD HOLD) required

Minimum AFCS configuration
to start IFR flight .... SAS 1, SAS 2 and ATTD HOLD mode ON

FLIGHT WITH ONE HELIPILOT OPERATIVE ONLY (SAS 1 or 2)

VFR Flight

Fly attentive up to 128 KIAS and/or 1000 ft/min rate of climb, and above 500 ft AGL.
Fly manually in all other conditions.

IFR Flight

The following limitations apply:
Maximum airspeed .... 128 KIAS
Maximum rate of climb .... 1000 ft/min

Fly attentive above 500 ft AGL.
Fly manually below 500 ft AGL.

1.6.8.1.a. Restrictions in the operation when a SAS channel is inoperative

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When only one SAS is operational, the helicopter's Flight Manual restricts its operation to visual flight rules and that the flight be conducted with a maximum speed of 128 knots and/or with a vertical speed

[28] According to the helicopter certification process, a simultaneous failure is considered when there is a 3.5 second difference between the occurrence of an initial failure and a second failure.

of 1,000 ft/min, and minimum height above ground of 500 ft; in all other conditions, the helicopter must be flown manually.

The following procedures are taken from Section 3 "Emergency Procedure" of the A109S Helicopter Flight Manual (Document No. 109G0040A013).

CAUTION

With the Flight Director coupled, following a single SAS failure or ATT mode failure, the AUTOTRIM function is inoperative.
Without the Flight Director coupled, the AUTOTRIM function is always inoperative.
In these conditions, the pilot is recommended to fly checking the API position or fly decoupled, due to the reduced system authority.

Note

HELIPILOT indicators normally refer to SAS 1. Turning SAS 1 off, HELIPILOT indicators will automatically switch to SAS 2.

1.6.8.1.b. Specifications with the coupled flight director and SAS malfunctioning

The emergency procedure indicates that with the FD (Flight director) engaged, after a SAS failure or an ATT mode failure, the AUTOTRIM function becomes inoperative.

Without the FD attached, the AUTOTRIM function is always inoperative; in these conditions it is recommended that the pilot fly by checking the API (Auto pilot indicator) position or fly undocked, due to the reduced authority of the system.

Note: The HELIPILOT indicators normally refer to SAS 1. When SAS 1 is switched to the OFF position, the HELIPILOT indicators will automatically switch to SAS 2.

1.6.8.2. Attitude mode OFF.

The following considerations were taken from Section 3, "Emergency procedure" of the A109S Helicopter Flight Manual (Doc N°109G0040A013: for some circumstance, when ATTD HOLD is selected, the selected attitude of the helicopter is not maintained, the procedure instructs to disconnect ATTD HOLD and continue with the flight.

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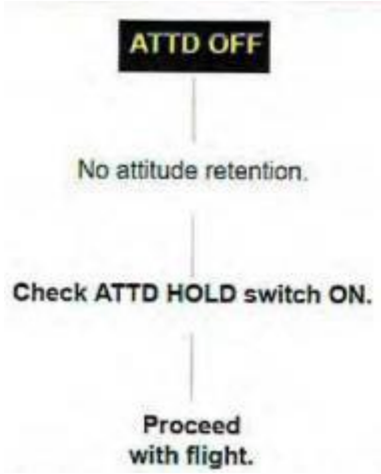
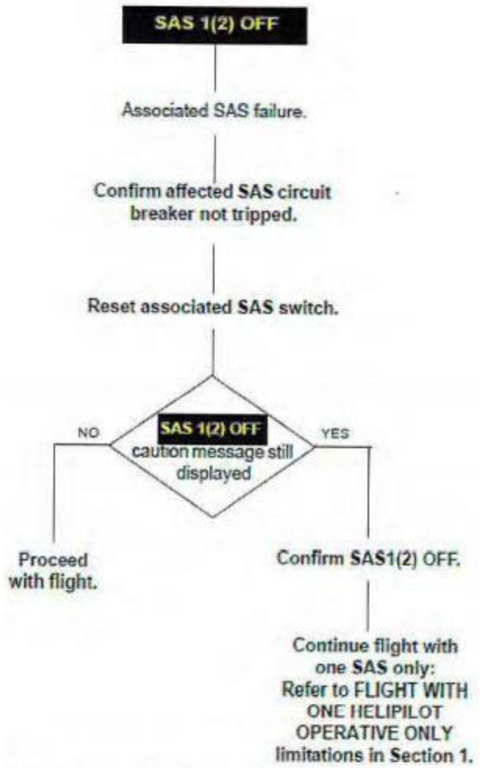


1.6.8.2.a. Relation of the flight director and the SAS

1.6.8.3. SAS 1 (or SAS 2) OFF.

The following consideration was taken from Section 3, "Emergency procedure" of the A109S Helicopter Flight Manual (Doc N°109G0040A013): When the helicopter is in flight and there is a functional failure of a SAS, the Flight Manual indicates that the first thing the pilot must do is to identify which SAS has the failure and confirm that the switch of the affected SAS has not been tripped; then the affected SAS must be reset through its switch and verify the caution message, if it disappears by following the procedure, the flight can continue; when the caution message remains on the device, confirm that the affected SAS is functionally OFF, and continue the flight with an operational SAS, with the restrictions indicated in point 1.6.7.1. of this document.



1.6.8.3.a. Restrictions on the operation of SAS malfunctions

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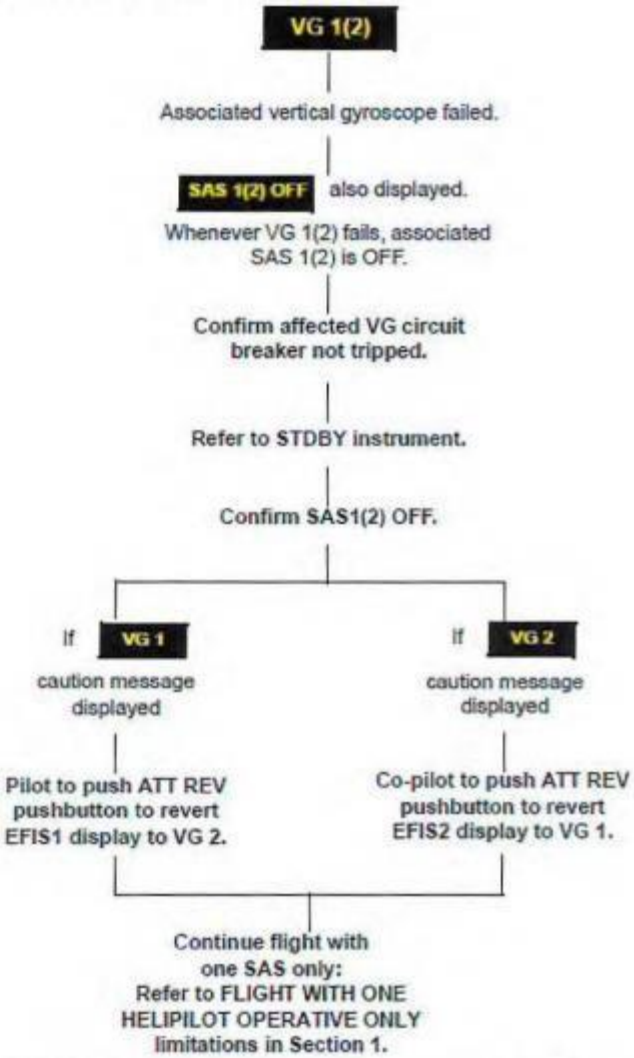
1.6.8.4. Vertical gyro failure.

The following consideration was taken from Section 3, "Emergency procedure" of the A109S Helicopter Flight Manual (Doc N°109G0040A013): When in the flight phase the failure of vertical gyro 1 (or 2) occurs, it is necessary to identify which vertical gyro failed, which will also be shown in the PFD (Primary Flight Display); any failure of vertical gyro 1 (or 2), is associated to SAS 1 (or SAS2), so it will be automatically disengaged; it must be verified that the vertical gyro circuit breaker has not been tripped and the instrument will be left in STDBY (Stand By).

It shall be confirmed that the affected SAS 1 (or 2) is disabled (OFF); if the functional failure and the caution message coming from the vertical gyro (VGl) is displayed, the pilot shall press the ATT REV button to revert the EFIS1 display to VG2, in case it is VG2 that presents the failure, the co-pilot shall press the ATT REV button to revert the EFIS2 display to VGl. For both conditions, the flight may continue with only one operative SAS, with the restrictions indicated in point 1.6.7.1. of this document.



1.6.8.4.a. Procedure for vertical rotation malfunction

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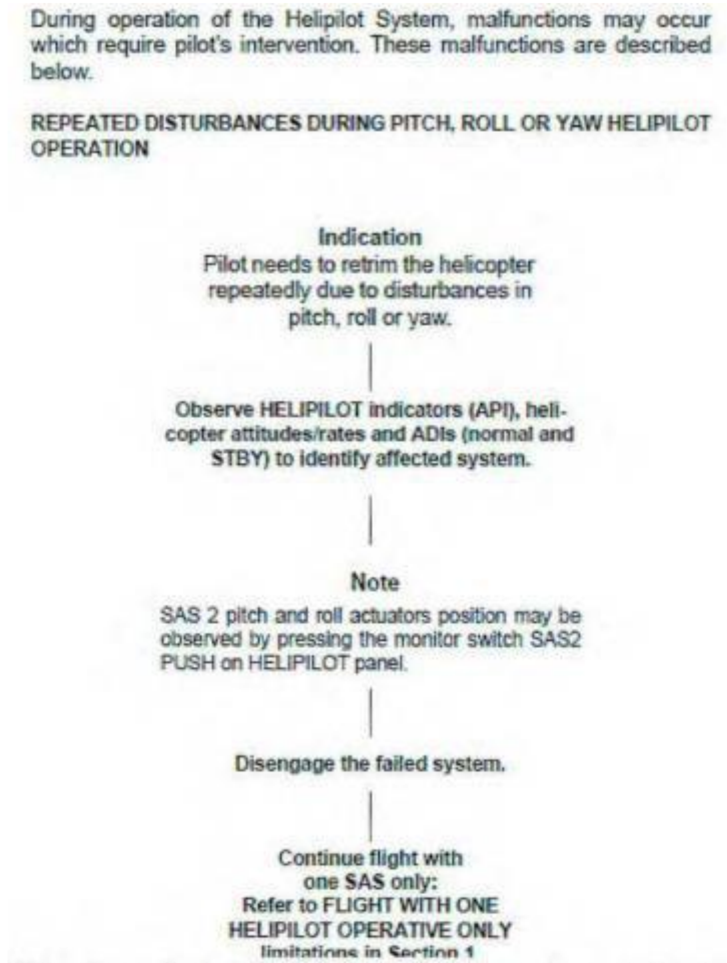
1.6.8.5. Helipilot malfunction.
During flight, the operation of the Helipilot system malfunctions may occur, requiring pilot intervention. These malfunctions are described below:

a) Repeated alterations during operation of the Helipilot in pitch, roll or yaw.

First, the pilot needs to retrim the helicopter constantly, due to pitch, roll or yaw alteration. He/she should observe the Helipilot Indicators (API), helicopter attitude/rate and ADI[29]s (normal and standby) to identify the affected system. Note: The SAS2 pitch and roll actuators can be observed by pressing the SAS2 monitor switch on the Helipilot panel, finally the failed system will be disengaged and the flight can continue with an operational SAS, with the restrictions indicated in point 1.6.7.1. of this document.


During operation of the Helipilot System, malfunctions may occur which require pilot's intervention. These malfunctions are described below.

REPEATED DISTURBANCES DURING PITCH, ROLL OR YAW HELIPILOT OPERATION

1.6.8.5.a. Helipilot malfunction procedure

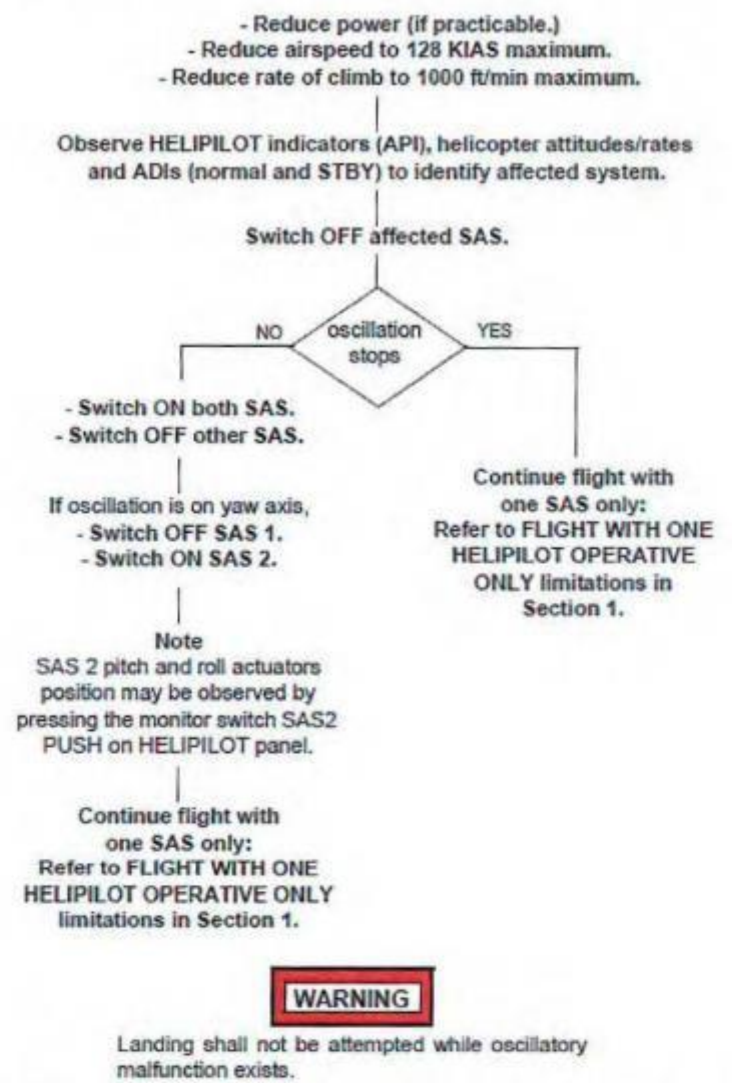
b) Malfunctions - oscillations.

In this scenario, power should be reduced (if possible), as well as speed to 128 KIAS maximum; the Helipilot indicators (API), helicopter attitude/rate and ADIs (normal and standby) should be observed; to identify the affected system, the corresponding SAS should be turned off; if the oscillations cease,

[29] Attitude Data Indicator

continue flying only with an operational SAS, with the restrictions indicated in point 1.6.7.1. of this document. If the oscillations do not cease, both SAS will be turned ON, one SAS will be disengaged, if the oscillations continue in the yaw axis, the SAS1 switch will be turned OFF and the SAS2 switch will be turned ON. Note: The position of the SAS2 pitch and roll actuators can be observed by pressing the SAS2 monitor switch on the Helipilot panel. It is possible to continue the flight only with an operational SAS, with the restrictions indicated in point 1.6.7.1. of this document.

Warning: Do not attempt to land while there is an oscillatory malfunction.



1.6.8.5.b. Procedure with oscillatory malfunction

In the failure possibilities of the systems described above, one of the constants is to slow down to 128 KIAS.

1.7. Meteorological information.

METAR MMPB 241945Z 18005KT 12SM FEW220 19/02 A3028 RMK 8/002 AC=

The METAR report issued by SENEAM at the Puebla station on December 24, 2018 at 1:45 p.m. (19:45 UTC) indicates: Wind with direction of 180° and an intensity of 05 knots (9 km/hr), visibility of 12 statute miles (20 km), existence of some clouds at 6705.6 m (22,000 ft), Ambient Temperature of 19°C and 02°C dew point temperature; also, the altimetry ruler was 30.28 inches of mercury. As indicated in the notes, scattered cloudiness prevailed at 22,000 feet (6705.6 m) altitude.

Report corresponding to the time of the accident:

METAR MMPB 242043Z 18012KT 12SM FEW220 21/00 A3027 RMK 8/002 AC=

The METAR report issued by SENEAM at the Puebla station on December 24, 2018 at 2:43 p.m. (20:43 UTC) indicates: Wind with a direction of 180° and an intensity of 12 knots (22 km/hr), visibility of 12 statute miles (20 km), existence of clouds at 6705.6 m (22,000 ft), Ambient Temperature of 21°C and 0°C dew point temperature; also, the altimetry ruler was 30.27 inches of mercury. As indicated in the notes, scattered cloudiness prevailed.

1.8. Communications.
The helicopter crew established communication with the Air Traffic Services of the Puebla Control Tower through the 118.20 Mhz frequency; the following is the transcription of the communications established between the air traffic services and the helicopter during the flight from the Puebla International Airport to the El Triangulo heliport (actually, in the yard of a house located in a different place), in the city of Puebla.

TIME UTC	UNIT	CONTENT OF COMMUNICATIONS
19:33:41	XA-BON	TOWER PUEBLA OF EXTRA ALFA BRAVO OSCAR NOVEMBER
19:33:50	TWR PBC	CONTINUE BRAVO OSCAR NOVEMBER
19:33:53	XA-BON	GOOD AFTERNOON AGUSTA ONE HUNDRED AND NINE SIERRA WE ARE IN SAASA WITH THE FLIGHT PLAN TO EL TRIANGULO WE ARE READY FOR TAKE OFF DATA PLEASE
19:34:05	TWR PBC	GOOD AFTERNOON BRAVO OSCAR NOVEMBER THIRTY TWENTY-NINE THE QNH WIND FROM THE SOUTH WITH SIX KNOTS AUTHORIZED FOR TAKEOFF AND RUNWAY CROSSING CALL FINAL
19:34:12	XA-BON	SOUTH SIX THIRTY-NINE AT THE ALTIMETER AUTHORIZED TAKEOFF AND TRAJECTORY CROSSING I CALL THE END TO EL TRIANGULO BRAVO OSCAR NOVEMBER THANK YOU VERY MUCH.
19:39:22	XA-BON	TOWER PUEBLA EXTRA BRAVO OSCAR NOVEMBER NOW FINAL LARGO EL TRIANGULO
19:39:31	TWR PBC	BRAVO OSCAR THE WIND AT THE STATION OF ONE HUNDRED AND TWENTY SIX KNOTS PENDING DEPARTURE
19:39:37	XA-BON	RECEIVED PENDING THE NEW DEPARTURE BRAVO OSCAR NOVEMBER THANK YOU VERY MUCH
		(END OF TRANSCRIPTION)

Below is the transcript of the communications established between air traffic services and the helicopter on the flight from el Triangulo (actually, in the backyard of a house located in another place) to Radio Capital.

COMMUNICATIONS
SECRETARIAT OF COMMUNICATION AND TRANSPORT

AFAC

Undersecretariat of Transport
Federal Civil Aviation Agency
Aviation Accident and
Incident Analysis Directorate

[Coat of arms: United Mexican States]

TIME UTC	UNIT	CONTENT OF COMMUNICATIONS
20:34:17	XA-BON	TOWER PUEBLA GOOD DAY OF EXTRA ALFA BRAVO OSCAR NOVIEMBRE LEAVING EL TRIANGULO BY EEH RADIO CAPITAL IN MEXICO CITY
20:34:35	TWR PBC	BRAVO OSCAR NOVEMBER THIRTY TWENTY TWENTY-SEVEN CALL TWO MILES BEFORE TO CROSS THE STATION
20:35:05	NO IDENTIFICATION	TOWER
20:35:16	TWR PBC	BRAVO OSCAR NOVEMBER DO YOU COPY
20:35:20	XA-BON	EXCUSE US IS THAT WE TURNED THE RADIO BACK ON EH NO NO I DIDN'T COPY YOU NOW WE ARE EH SIX POINT SIX MILES FROM THE AIRPORT EH AND WE ARE GOING BY CAPITAL RADIO
20:35:36	TWR PBC	BRAVO OSCAR NOVEMBER WITH THIRTY-TWENTY-SEVEN QNH WITH NO TRAFFIC CALL CROSSING OVER STATION
20:35:40	XA-BON	THIRTY TWENTY-SEVEN NO TRAFFIC WE CALL YOU ACROSS THE STATION EL BRAVO OSCAR NOVEMBER
20:39:29	TWR PBC	BRAVO OSCAR NOVEMBER THE STATION HAS ALREADY PASSED
20:39:49	TWR PBC	BRAVO OSCAR NOVEMBER FROM TOWER
20:40:08	TWR PBC	BRAVO OSCAR NOVEMBER FROM TOWER
20:40:54	TWR PBC	BRAVO OSCAR NOVEMBER FROM TOWER PUEBLA
20:41:28	TWR PBC	BRAVO OSCAR NOVEMBER FROM TOWER PUEBLA
20:42:01	TWR PBC	BRAVO OSCAR NOVEMBER FROM TOWER PUEBLA
20:43:02	TWR PBC	BRAVO OSCAR NOVEMBER FROM TOWER PUEBLA
20:44:01	TWR PBC	BRAVO OSCAR NOVEMBER FROM TOWER PUEBLA
20:44:59	TWR PBC	BRAVO OSCAR NOVEMBER FROM TOWER PUEBLA
20:46:47	TWR PBC	BRAVO OSCAR NOVEMBER FROM TOWER PUEBLA
20:49:11	TWR PBC	BRAVO OSCAR NOVEMBER FROM TOWER PUEBLA
		(END OF TRANSCRIPTION)

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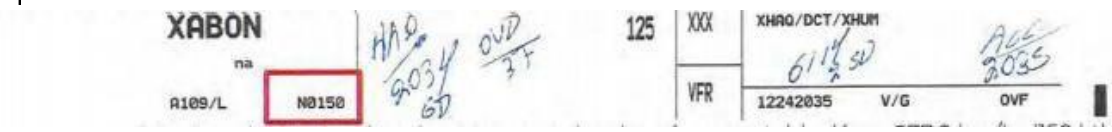
According to the flight progress strip, filled out by the Air Traffic Controller of Puebla Control Tower, it is stating that the helicopter would carry a speed of 277.8 km/hr (150 Kt), information provided by the Operator.



1.8.1. The estimated speed at which they would travel was set at: 277.8 km/hr (150 kt).

1.9. Airfield information.

It is not relevant to the investigation of this event, although it should be noted that a visual corridor is not published in the PIA; according to air traffic services the crossing of the station is in accordance with instructions from Puebla control tower, which gave direct flight instructions to the station.

1.10. Flight recorder.

The helicopter was not equipped with a flight data recorder (FDR), nor with a voice recorder (CVR), as it was not required by aeronautical regulations for the maximum take-off weight and number of passenger seats of this type of aircraft.

As for non-volatile memory components, all the equipment inherent to this type of helicopter was located; however, no information was recovered from them because they were destroyed due to the impact and fire. See point 1.15.3 of this report.

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1.11. Helicopter wreckage and impact information

The helicopter impacted against the surface of a crop field (farmland, flat and with little vegetation), initially hitting the red and yellow main rotor blades, which were 1.8 m below ground level; the blue and white blades did not show as much damage, because the first two absorbed the energy of the initial impact against the ground. The helicopter was in an inverted position, with the landing gear retracted. A graphic of the helicopter wreckage can be seen in Annex A Sketch of the accident.

Most of the wreckage, including the projected parts, was found in a triangular area of 600 m^2. After the impact the helicopter started to catch fire, this caused the destruction of the basic body; the main rotor was located on the left side of the fuselage. The main rotor core still had the root of the four main rotor blades attached, the leading edge of the four blades showed major damage and the blade spars were destroyed. The elastomer bearing of the red blade was detached from its housing in the main rotor core support. The marks on the ground and other evidence indicate that the four main rotor blades were fractured when they hit the ground, and their trailing edges were detached from their design location.

The landing gear showed impact and fire damage, the nose leg showed less damage, while the left and right legs showed the same impact and subsequent fire damage. The landing gear control was observed secured and the cylinders of the 3 (three) legs denoted that they were lodged, i.e. up and secured.

The evidence indicates that the main rotor entered rotating at the moment of impact, the mechanics of destruction of the basic body indicates that the attitude with which the helicopter impacted the ground was inverted, with an estimated inclination of 60° with respect to the surface of the helicopter.

The boom was detached by torsion and impact, it was not cut or hit by any of the main rotor blades during the strike sequence, so it remained attached to the basic body until it was detached by the mechanics of destruction and fire, and it was also located in an inverted position.

The two tail rotor blades, the tail rotor core and the 90° gearbox were present and damaged on impact, but not affected by fire, showing evidence of having been operating and rotating; both components were detached from the boom. The magnitude of the damage is an obvious consequence of the impact described above, indicating a sudden stop of the main and tail rotors upon impact with the ground.

The nose section of the helicopter and the crew and passenger cabins were destroyed by impact and subsequent exposure to fire, as well as the electronic components and devices. The avionics section and the power plant (2 engines) were damaged by impact and fire exposure.

The fuel tanks were not physically found, because the impact caused them to rupture and the spilled fuel, falling on hot and electrical parts of the helicopter, caused the fire that burned them.

Fig. 1.11.1. XA-BON helicopter damage.

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1.12. Medical and pathological information.

The SCT experts in the investigation of the human factor, having analyzed the information provided by the Attorney General's Office of the State of Puebla, corresponding to the necropsy protocol and toxicological analysis of the crew members, highlight the following:

a. Body registered as unknown number 454: identified as the commander of the helicopter. Cause of death: traumatism. In the chemical-toxicological results, no ethyl alcohol, cocaine, marijuana, amphetamines, benzodiazepines or barbiturates were found.

b. Body registered as unknown number 451, identified as the co-pilot of the helicopter. Cause of death: Traumatism. In the chemical-toxicological results, no ethyl alcohol, cocaine, marijuana, amphetamines, benzodiazepines or barbiturates were found.

The human factor research was carried out based on scientific, retrospective (background), inductive (elements of importance from the general to the particular), analytical (physical and electronic clinical records) methods, as well as interviews with family members of the deceased and their colleagues in the workplace.

The report states that there is a discrepancy in the responses of the maintenance personnel who performed the last services, since they indicated that the helicopter was in excellent condition for navigation and had all the preventive maintenance, according to the manufacturer's manual; however, in the meetings of the Investigation Commission, the Investigator in Charge reported that there was evidence of malfunctioning of the autopilot (SAS).

The pilots had valid medical certificates and complied with the medical requirements for aeronautical technical personnel.

In relation to the analysis of the medical information contained in the clinical records, both physical and electronic, and the information received from the company, it was determined that there was no disorder or psychophysical condition of the human factor that could have contributed to the genesis of the accident.

According to the autopsy report, the toxicological analysis and the genetic recognition protocol performed by the Attorney General's Office of the State of Puebla, it is concluded that the bodies found

at the accident site correspond to those of the aircraft commander and the First Officer; furthermore, no evidence of substances of abuse was found. The cause of death was ante and post mortem polytraumatism, with post mortem burns.

According to the information obtained, there is no factor of personal, family and/or social origin that could be determinant for the genesis of the event.

There is evidence, in e-mails, among others that infer that the aircraft commander and the co-pilot were aware that the SAS2 linear aileron actuator was malfunctioning and that they were looking into the possibility of changing it; however, they continued to operate the helicopter due to flight commitments already acquired.

1.13. Fire.
The high-energy impact against the ground caused the helicopter's fuel tanks to rupture; when the fuel spilled and came into contact with hot parts of the engines and/or electrical-electronic components, the fire started and consumed the helicopter.

1.14. Survival.
Both pilots and the three passengers were fatally injured as a result of the heavy impact with the ground and their remains were also consumed by the fire.

Due to the fire destruction of the helicopter, it was not possible to assess the seat structures, seat belts and emergency equipment on board.

The helicopter had an Artex brand Emergency Locator Team (ELT) model 455- 5049-345 See 3 series with an Artex brand battery model 452-0133 series See 3 installed on November 09, 2016, expiring in October 2021.

From various reports (see Attachment A numeral 13) it is known that the Second Section of the General Staff of the Secretariat of the Navy reported that the ELT radio beacon of the helicopter had been activated nine minutes after takeoff, at 2:43 p.m. (21: 25 UTC), however, they did not make the official notification to the Puebla Airport Command (Search and Rescue Coordination Center), and the first communication from the controller took place at 2:39:29 p.m. (20:39:29 UTC) trying to locate the helicopter, however there was no answer.

The search and rescue activities were initiated by the Air Traffic Controller of the Puebla station, who issued the incerfa phase when no response was received from the XA-BON; also the residents of Santa Maria Coronango observed the accident and immediately reported it to the municipal police, who were the first responders, cordoning off the site; the municipal police indicated in their report that the San Pedro Cholula Fire Department arrived at approximately 2:55 p.m. (20:55 UTC), successfully extinguishing the fire completely at approximately 3:25 p.m. (21:25 UTC). The airport command received notification from the C-4 (Command, Control and Computer Center, Public Security Council of the State of Puebla) who confirmed the occurrence of an air accident, thus closing the alert notifications for the occurrence of an air disaster.

1.15. Tests and investigations.
1.15.1. Inspection of the remains.

After the accident, the wreckage of the helicopter was inspected on site; at the end of the inspection, it was determined that the field investigation phase was concluded, thus

the investigator in charge coordinated the transfer of the remains of the helicopter to a hangar where, to date, they remain under the surveillance and custody of the Attorney General's Office of the State of Puebla. The group of investigators continued their procedure by conducting more detailed inspections of the structure and systems.

The inspection of the wreckage began by placing it, in order, on a sketch of the helicopter drawn on the hangar floor, to identify the components, the mechanics of destruction, the pre-impact layout and the analysis of the logic and mechanics of the impacts.

The following are the most important parts of the report of the investigator-in-charge on the helicopter reconstruction.

1.15.2 Initial inspection of the remains of the basic body.
The wreckage recovered at the accident site was placed in its design position, but given the destruction of the helicopter by fire, it was not possible to perform a detailed analysis of the structure of this section; however, the following was obtained:

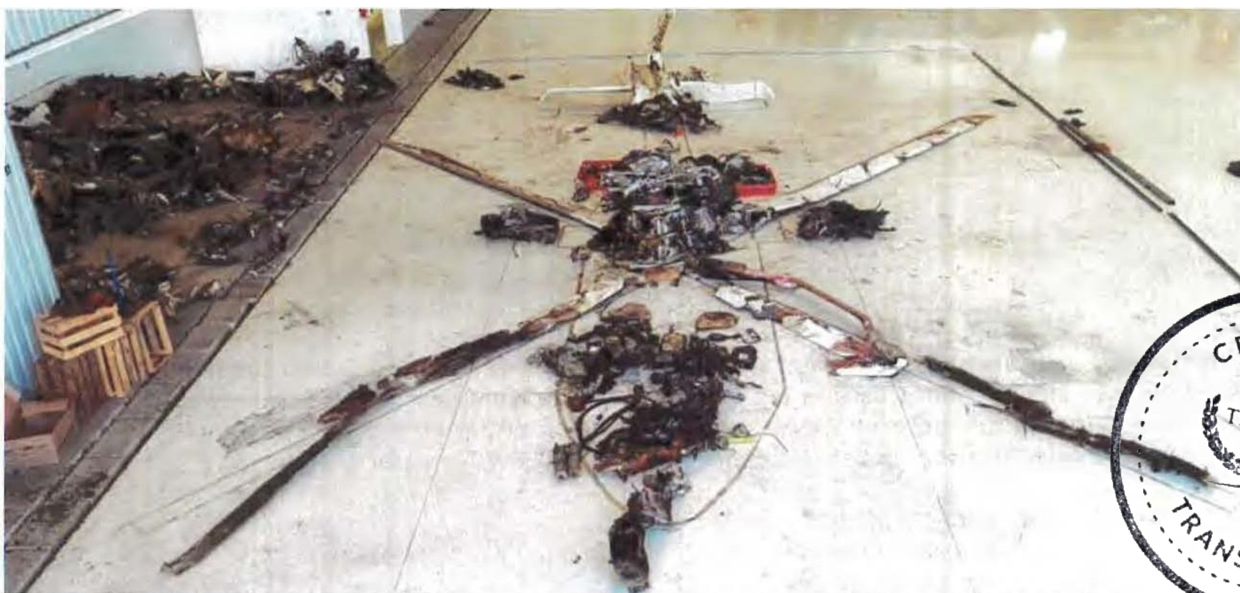

Fig. 1.15.2.1. Reconstruction of the helicopter with the remains of the main components.

The Commission, based on the witness statements from which it is inferred that the helicopter had a loss of control in flight and based on the analysis of the interviews with RFS technicians and the maintenance evidence, decided to focus the inspection on the components mentioned below:

Description	Part number	Serial number
Main Transmission (MGB) Upper Case	109-0402-45-101	See reference 3
Swashplate and Support Assembly	109-0134-02-103	
Support Assembly	109-0134-29-101	
Main Rotor Hub Assembly	109-0112-02-103	See Reference 3
Main Rotor Servo Actuator	109-0110-42-134	
Main Rotor Servo Actuator	109-0110-42-135	
Main Rotor Servo Actuator	109-0110-42-136	
Mast Vibration Absorber Kit	109-0824-40-103	

The main transmission section and the 90º gearbox were located among the wreckage, although they showed impact damage; it was determined that due to their function in the control of the helicopter, it was important to perform a more detailed inspection.

Description	Part number	Serial number
Main Transmission Assembly	109-0400-03-119	See reference 3
Tail Rotor Gearbox. TGB 90º	109-0400-01-123	

The flight control instruments and controls were also destroyed; only the right-side radio altimeter was rescued, which is shown in figure 1.15.2.2, showing a reading of 1,600 feet (1,025 hPa setting).

Fig. 1.15.2.2. Radio altimeter with the indication of 1,600 feet above ground.

The three switches still present on the Helipilot Control Panel recovered from the wreckage were SAS1/2 and ATT HOLD, while the COUPL and AUTO TRIM were no longer present. It should be noted that the SAS1/2 and ATT HOLD switches are magnetically held, and the default positions when no 28 VDC power is applied to the panel are:

- SAS1: OFF
- SAS2: OFF
- ATT HOLD: ON

Description	Part number	Serial number
Engine Control Lever	109-0630-61-109	Illegible
Master Caution and Master Warning Push-Buttons	109-0729-43-1	Illegible
Helipilot Control Panel Assembly	109-0729-49-1	Illegible

Finally, another vital component for the control of the helicopter is the tail rotor, which was found with impact damage; this section was the least affected by fire. Among the most important parts, the following were found:

Description	Part number	Serial number
Tail Rotor Drive Shaft	109-0425-41-1	See reference 3
Hanger Assembly Bearing	109-0422-01-3	
T/R Hub & Blade Assembly	109-0162-01-107	

Upon completion of the reconstruction of the helicopter, the investigators and experts decided to visit Leonardo Helicopters Division's facilities in Cascina Costa, Milan, Italy, to witness and analyze in detail the components listed above.

At the end of the activities in Cascina Costa, Milan, Italy, on March 13th, 2019, the Investigator in charge and the representative of the manufacturer in Mexico, located among the remains of the helicopter, located in a Hangar of the Puebla International Airport, the following components, which were sent to the NTSB in the City of Washington D.C., in the United States, to undergo destructive testing:

Description	Part number	Serial number
Master Caution and Master Warning Push-Buttons	109-0729-43-1	See reference 3
Right Hydraulic Pump	109-0760-42-105	

1.15.3. Initial inspection of engine wreckage.
Both engines were found detached from their mounts, showing external impact damage with deformations and dents; exposure to fire affected these components and their external accessories. It is worth mentioning that the fuel management modules (FMM) were not detached from the engines.

The electronic control components of the engines, such as the EEC (Electronic Engine Control) and DCU's (Data Collection Unit) were damaged due to the high temperature (including fire), however, they were sent to the laboratories of their respective manufacturers for inspection. The FMM's (Fuel Management Modules) were left installed in the engines and were inspected at the same time the engines were disassembled.

After the initial inspection at the accident site, given the extent of the damage to the main rotor blades, it was determined that there was no indication that the engines had contributed to the accident, however, the team of investigators and experts decided to jointly send the engines to the manufacturer Pratt & Whitney Canada, at their St. Hubbert, Montreal facility, for further inspection.

1.15.4. Laboratory inspections.
Destructive and non-destructive testing activities were scheduled for the basic body components and engines at the facilities of the manufacturers, which were carried out on the following dates:

1. Meeting of the Investigating Commission in St. Hubbert, Montreal, to be present at the disassembly and inspection of the engines, from March 04th to 08th, 2019. The results of these activities are presented in Annex B. Inspection of the engine wreckage.
2. Commission meeting for disassembly and inspection of the flight controls (rotors, transmission, 90° gearbox and main components) of the helicopter, at the facilities of the manufacturer Leonardo Helicopters, located in Cascina Costa, Milan, Italy, from April 01st to 12th, 2019. The results of these activities are presented in Annex D. Inspection of the Flight Controls and Annex C. Inspection of DAU, MC, MW and Audio.
3. The manufacturer Leonardo Helicopters, coordinated the performance of the computerized tomography (CT Scan) on the three hydraulic servo actuators, from April 29th to 30th, 2019 at Collins Aerospace facilities, Brugheiro, Milan, Italy; the results of these activities are presented in Annex D. Inspection of the Flight Controls, subsection 1.4.5.

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4. On May 09th, 2019, the NTSB sent to the group of investigators the report of the CT scan performed to the five electromechanical linear actuators. This activity was performed at Varex, Chicago, Illinois, USA; the result is presented in Annex E. Inspection of the Linear Actuators, section 1.
5. The manufacturer Leonardo Helicopters, coordinated the performance of the disassembly of the three hydraulic servo actuators, on June 5th, 2019, at Collins Aerospace facilities, Brugheiro, Milan, Italy; the results of these activities are presented in Annex D. Inspection of the Flight Controls, section 1.4.6.
6. Investigating Committee meeting in Boyne City, Michigan, USA, to be present at the opening and inspection of the electromechanical linear actuators, from July 23rd to 24th, 2019. The results of these activities are presented in Annex E. Inspection of the Linear Actuators, section 2, Destructive Inspection of the Linear Actuators.
7. Meeting of the Investigative Commission in Washington, D.C., USA, to be present at the opening and inspection of the right hydraulic pump (see subsection 1.5.2. Right hydraulic pump of Annex D. Inspection of the Flight Controls), of the master caution and master warning lights (see non-destructive inspection of the master caution (MC) and master warning (MW) indicators, of Annex C. Inspection of the DAU, MC, MW and Audio, from July 25th and 26th, 2019.
8. On October 15th, 2019, LHD and Honeywell jointly developed a report on what a loose screw causes when moving freely on the linear actuator electronics board, which is presented in section 3 of Annex E. Inspection of the SAS1 Roll Actuator, following up on the tasks assigned at the Commission Meeting in Boyne City, Michigan, USA.
9. On December 30th, 2019, the NTSB, following up on the tasks assigned at the Commission Meeting in Boyne City, Michigan, USA, developed its report of the inspection of the roll linear actuator body, which is presented in Annex E. Inspection of the Linear Actuators, item 4.

The activities and their results are described in the Annexes, which are supported by the reports of the experts from the manufacturers.

1.15.5. Witness statements.

Several interviews were conducted with witnesses of the accident, although it is worth mentioning that none of these witnesses are aviation experts; however, they provided important information, as follows:

> Witness 1 ***"I was taking care of the cattle about 100 meters away... I heard a noise as if gas was escaping with pressure; when I turned to the sky, I realized it was a helicopter... it suddenly lost altitude and began to plummet, turning in a spiral... I heard a loud explosion..." [sic]***
>
> Witness 2 ***"When I heard the sound of a helicopter, I look up and see a white one; I could hear it was flying low and it was going normally, when I hear a sound as if the engine was "drowning", it kept moving forward and suddenly I stopped hearing the engine, although the propellers were still turning, that is when it stopped completely, without making any kind of maneuvers or landing, it plummeted" [sic].***

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Witness 3 ***"I heard a white helicopter pass by; as it passed above my house, I heard a change in the sound of the helicopter's engine, and as I continued to observe it I noticed how it began to turn around, circling approximately three times... noticing that its impact was from the tip forward, catching fire at the moment of impact" [sic].***

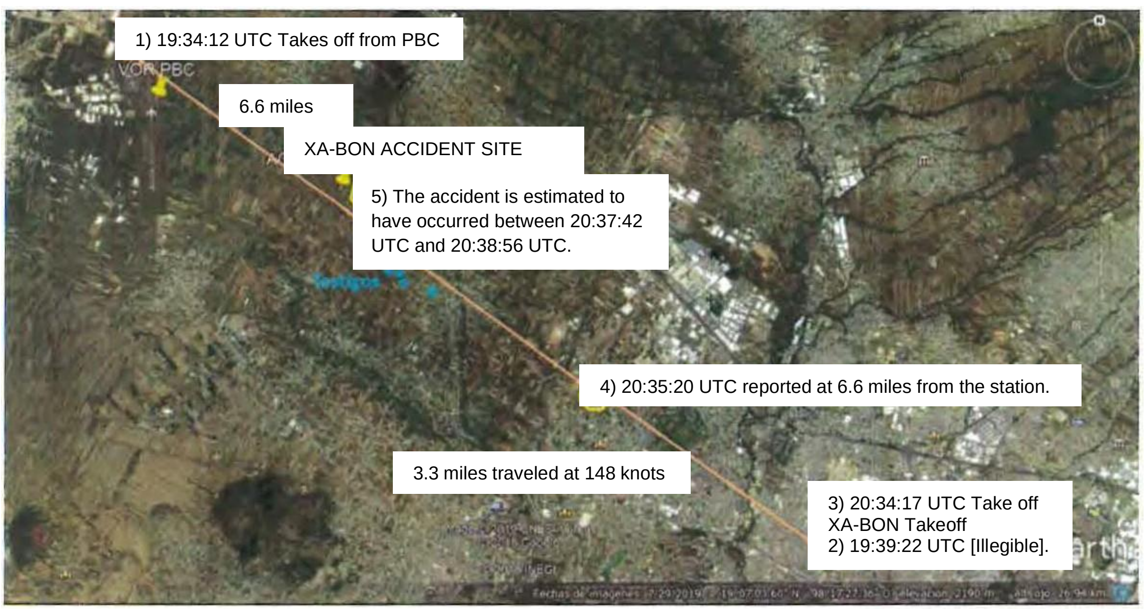
Witness 4 ***"I heard like an acceleration, when I looked towards the sky, I saw a helicopter, which was upside down, then it turned around and took its position again after a minute or two; that's when the helicopter started to fall" [sic].***

Witness 5 ***"The helicopter was going up here and started buzzing; it was going all normal until an engine noise was heard and it started to rattle (makes movements on the yaw axis) and then it started to fall and turn (to the left); it headed towards those houses; the helicopter was not smoking and I didn't see anything coming off; it started to fall while turning (to the left)" [sic]***

1.15.6. Aircraft trajectory.

Based on information from witnesses and communications established with the Puebla Control Tower, a graph was made to show approximate distances and times.

There is a distance of 9.97 NM (18.5 km) from the takeoff site (home yard located at latitude 19° 04' 6.8" North, longitude 98° 13' 26.7" West) to the VOR PBC, bearing to 303 degrees; the distance from the takeoff site to the point where the co-pilot reported they were 6.6 NM (12.2 km) from the VOR PBC, is 3.37 NM (6.2 km). From the takeoff site to the accident site there is a distance of 7.45 NM (13.8 km) with a bearing at 306 degrees.



1.15.6.1. XA-BON flight trajectory graph.

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1.16. Navigation aids.

In accordance with the procedures for crossing the airfield under visual flight rules (VFR) over the Puebla station, this is instructed by the Control Tower Controller, and must be performed between 9,000 and 9,500 feet MASL, i.e., 1,500 and 2,000 feet above the ground.

It should be noted that this crossing procedure is not published in the Aeronautical Information Publication Manual (PIA).

1.17. Organizational and management information.

1.17.1 Servicios Aereos del Altiplano, S.A. de C. V.

It has an Air Services Operator Certificate, number ATP/2014, to provide the domestic non-scheduled passenger air cab service No. TAN-TN-778 and international non-scheduled passenger air cab.

In April 2017, SAA made the inclusion of the Agusta aircraft, model A109S, registration XA-BON, to its AOC, being authorized by the DGAC.

On December 19th, 2018, it obtains the renewal of the Air Services Operator Certificate. The air operator had a contract for the provision of maintenance and technical administration services with RFS aeronautical workshop, type 24/7[30], the seventh clause of which established the following:

> ***"(...) It shall be the responsibility of THE COMPANY to keep the official documents of the crews and maintenance personnel in order, such as the Aeronautical License, medical certificate, flight log for pilots... (...)" [sic].***

Likewise, in the eighth clause it states:

> ***"(...) It is the responsibility of the aircraft crews, together with the maintenance personnel, to carry out pre-flight and post-flight inspections, as well as to fill out the flight logs and keep them updated, in addition to recording in the same document each and every discrepancy or failure detected during the operation; they must report it to the person in charge of the maintenance area, to apply corrective measures, all this with full knowledge of THE CLIENT ... (...)" [sic].***

In the General Maintenance Manual dated December 4th, 2017, revision 6, Chapter VIII, TRACKING AND CONTROL OF LOGS AND CONTINUOUS WORK REPORTS section, it states:

> ***"(...) ... the Maintenance Manager will keep in close communication with the Authorized Aeronautical Workshop Manager ... as well as ROTOR FLIGHT SERVICES S de RL de CV, for the Agusta A109S helicopter with registration number XA-BON, ..., in order for these reports noted by the pilot to be taken care of as soon as possible, and not to become deferred, the Logbook Forms applicable to each aircraft*** (helicopter) ***are specified in Annex II of this Manual The Maintenance Manager and the Manager of the contracted Authorized Aeronautical Workshop shall verify the reports of the pilot in each of the pages of the logbook after each flight; they shall also compute the total hours after each flight to determine the continuity of the operations according to the services***

[30] 24/7, being available 24 hours a day, 7 days a week.

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> ***of a preventive nature to be carried out. Depending on the operation program and the reports of the pilot, it will be determined if the helicopter is airworthy; the reports that cannot be attended before the next flight will be marked as "continued", noting such situation and the reason for it. When the reports are satisfactorily carried out and the responses thereto have been noted, the contracted Authorized Aeronautical Workshop shall be responsible for certifying the work performed in the aircraft's*** (helicopter's) ***logbook. (...)" [sic].***

In the same manual, in the ATTENTION OF OUT-OF-OPERATING-BASE PILOT REPORTS section, in point two it is mentioned:

> ***"(...) In case of failure, the crew will maintain constant communication with the Maintenance area, in order to be advised and to be able to report the failure if possible and defer it under the MEL, if applicable. (...)" [sic].***

Subsection b) MEL Management Program, which establishes the Air Service Operator Certificate (AOC) states the following:

> ***"(...) The certificate holder shall develop and maintain an adequate program for the management of repairs to the components and/or accessories listed on the approved MEL. In addition, the certificate holder shall include in a document or in its manual a description of the MEL management program. The MEL management program shall include at least the following:***
> ***1. A method that provides tracking of the date and, where appropriate, the time by which the component and/or accessory was deferred and subsequently repaired. The method should include a review of the number of each deferred component and/or accessory to determine the reason for any delay in repair, length of the delay and the estimated date by which the component and/or accessory will be repaired.***
> ***2. A plan to concentrate parts, maintenance and aircraft personnel to a specific time and place for repair.***
> ***3. A review of components and/or accessories deferred due to unavailability of parts, to ensure that a purchase order with a firm delivery date exists.***
> ***4. A description of the specific duties and responsibilities by position, in accordance with the organizational chart of the certificate holder, of the personnel in charge of handling the MEL management program. (...)" [sic].***

The General Operating Manual, revision 7, in the "Minimum Equipment List and Missing Parts List" section, states:

> ***"(...) The Director of Operations, the flight crew and the Operations Officer, and the personnel of the contracted Authorized Aeronautical Workshop will coordinate everything necessary to ensure that the aircrafts do not fly with Minimum Equipment List (MEL) reports; it is also established that: The flight crew will be responsible for: 1. Annotating in the aircraft logbook all irregularities found before, during, and after each flight. 2. Reviewing the list of deferred reports on the cover of the flight log and sharing the list of reports with the operations and maintenance procedures of the MEL section. 3. The aircraft shall not depart a station in an unairworthy condition or with less than that specified in the MEL. 4. The flight crew may defer only these reports covered***

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by the MEL; only certified maintenance personnel can take appropriate corrective measures."

"It is the policy of the Director of Operations of the company not to conduct operations when being limited by MEL. 1. A written report as a discrepancy that does not have to be repaired immediately does not make the aircraft inoperative or unairworthy; a MEL check will be made and only the listed report may be deferred. 2. The deferred report will be allowed to be made outside of any major inspection, except if the reports are not of an airworthy nature or parts are unavailable; the determination is made by the Operations Manager and the Authorized Contracted Aeronautical Workshop Manager, that the report can be safely carried until the parts can be obtained; in the case of deferred or continued components or units, it is required to placard them in accordance with the MEL; then, that component or unit will be identified in the cockpit. 3. When all logbook pages have been used and there are deferred reports lagging behind, these reports will be transcribed onto the new logbook page by the flight crew or by the contracted Authorized Aeronautical Workshop".

Finally, in the "Dispatch Criteria" section, it was stated:

"The Captain, as a general rule, shall comply with the MEL; however, in special cases due to operational conditions, he may request higher requirements than the minimum requirements listed and, on the contrary, he shall never accept lower requirements than those established. Before dispatching an aircraft with multiple inoperative MEL items, it must be verified that no internal facet or interpellation between inoperative items will lead to a degradation of the safety level and/or unnecessary work overload for the crew. It is particularly in this area of multiple discrepancies, and especially discrepancies in related systems, where good judgment must be used, based on the circumstances of the case, including weather and route conditions."

Regarding "Maintenance actions", it states:

"The maintenance personnel of the contracted Authorized Aeronautical Workshop shall correct as soon as possible any technical irregularities, in order to deliver the aircraft in fully operational conditions, when for reasons of lack of time, lack of spare parts or lack of means, a failure cannot be corrected; maintenance will complement the deferred item in flight technical part in accordance with the established procedure, labeling in the cabin the controls or indicators that are accessible by the crew and specified in the MEL, and applying, if so described in the MEL, the relevant maintenance procedure".

The air operator had an Operational Safety Management Manual, approved on December 19th, 2018, i.e., they were in phase 1 of the certification process, so their operational safety system was being implemented, there being no operational safety certification and surveillance.

On July 27th, 2016, the manufacturer Leonardo Helicopters (LHD) received notification that the air operator Servicios Aereos del Altiplano S.A. de C.V. had acquired the helicopter model A109S, series 22174, registration XA-BON. The previous owner (Eolo Plus, S.A. de C.V.) also informed LHD that the Helicopter Flight Manual issued by the European Aviation Authority (EASA Rotorcraft

Flight Manual - RFM) and the corresponding Optional Equipment Supplements (OES) would be delivered to the aircraft operator.

On July 29th, 2016, LHD provided SAA with the following publications: EASA RFM, OES, Service Bulletins (SB) and Maintenance Program (Aircraft Maintenance Information Planning - AMPI).

In the absence of a response from SAA, on December 23rd, 2016, LHD created an account to ensure that SAA had full-time access to the above publications (EASA RFM, OES, SB and AMPI).

Since then, LHD regularly sent the subscription quotation for all available technical information on the A109S helicopter, without receiving any comments or requests from SAA.

1.17.2. Rotor Flight Services S. de R. L. de C. V.

Rotor Flight Services S. de R. L. de C. V., has aeronautical workshop permit number 371 based at the International Airport of Toluca City, State of Mexico; being authorized to develop activities in the following classification:

- Category 3 Service to the public
- Class 1 and 2[31] helicopters
- Class 3 engines
- Class 2 accessories
- Specialized Services

Rotor Flight Services has an Aeronautical Workshop Procedures Manual, in its revision 3 dated May 11th, 2018 authorized by the Aeronautical Authority, Chapter 5, "Procedures for the control and follow-up of logbook reports and continued work" section, it states that the inspection area:

> ***"(...) 2.- Shall annotate such situation of the flight log in the continued reports control log and the reason for these, as well as those affected by MEL, must be recorded including the category and the date on which the problem must be corrected. (...)" [sic].***

Likewise, in point three it states:

> ***(...) ... shall inform the corresponding areas of the needs to address, and correct the logbook reports or, if applicable, conclude with works registered as continued (...)" [sic].***

The RFS workshop has an Operational Safety Management Manual, approved on October 23rd, 2018, so it was in phase 1 of the certification process. The safety system was in the process of implementation, so there is no operational safety certification and surveillance.

[31] The Agusta helicopter is classified as Class 2, with a maintenance level of up to 3200 h/24 months.

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1.17.3. General Directorate of Civil Aeronautics (currently AFAC).

According to the last extraordinary major technical-administrative verification performed by the DGAC, now AFAC, to the air operator Servicios Aereos del Altiplano, S. A. de C. V., carried out in January 2019, the following findings were found:

- The air operator does not have a Training Manual (Education and Training) approved by the Aeronautical Authority.

- There is no documentary evidence to support the teaching of these courses:
  a. Initial or periodic on aviation safety.
  b. Initial or periodic on Controlled Flight into Terrain (CFIT).
  c. Initial or periodic on the subject of "Executing the duties and functions required in the event of an emergency or helicopter evacuation".
  d. Initial or periodic on the topic of "Handling of helicopter emergency and rescue equipment."
- The company did not present documentary evidence to demonstrate that it had provided initial training on the Agusta Westland A109 equipment to the pilot in command involved in this accident, as established in its General Operations Manual.

The air operator submitted to the DGAC the evidence, including the training and education program, contained in the General Operations Manual, Chapter IV, pages 1 to 9; including CFIT, RVSM, initial or periodic training on aviation safety and human factors.

Likewise, they presented documentary evidence related to the initial training on the Agusta Westland A109 equipment provided to the commander involved in the accident, which is consistent with the information gathered by the investigators.

On December 19th, 2018, the DGAC authorized the renewal of the Air Services Operator Certificate (AOC) to SAA; in said document, section D81 "Authorization of minimum equipment list of the AOC", the Aeronautical Authority authorizes SAA to use the approved MEL for each of its aircrafts, as well as a MEL management program[32]; however, this document does not include the policy established in the "Regulatory Appendix" section, point 5.8 of the official Mexican standard NOM-018-SCT3-2012 "That establishes the content of the Flight Manual", which states: ***"The permit holders and concessionaires of the air transport public service must keep the information contained in the MEL updated, when: … -A new revision to the MMEL is published";*** however, this policy does not state the adequate time that the Operator has to implement the update of the MEL and submit it to the Aeronautical Authority for its approval.

1.18. Additional information

At 13:34:05 hours (19:34:05 UTC) the XA-BON was authorized to take off from the platform of the Servicios Aereos del Altiplano hangar at the Puebla City International Airport; at 13:39:22 hours (19:39:22 UTC), the XA-BON notified Puebla Control Tower that it was making a long final landing at the El Triangulo heliport, i.e., it covered the flight in approximately 00:05:17 hours; the approximate straight line distance was 9.97 NM (18.5 km), so it was estimated that it had an approximate speed of 113 knots (209 km/h); this calculated speed was below the restriction speed of 128 knots (237 km/h) established by the Flight Manual when a SAS is inoperative.

[32] Management of repairs to components and/or accessories listed on the approved MEL.

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At 14:34:17 hours (20:34:17 UTC) the XA-BON reports that they are leaving the El Triangulo heliport, at 14:35:20 hours (20:35:20 UTC) the XA-BON reports to be at 6.6 NM (12.2 km); from the VOR PBC, which means that in 00:01:03 hours it covered an approximate distance of 3.37 NM (6.3 km); according to this data, the helicopter should have reached an approximate speed of 192 knots (355.6 km/h); which is even higher than the speed never to exceed (Vne) and the maximum designed speed of the helicopter, so it is deduced that the crew reported at a different point than the one where it was actually located in space; therefore, it is not feasible to know the real speed of the flight.

The approximate distance that the helicopter traveled from the garden of the house to the site of the accident was 7.45 NM (13.8 km). Also, it is known that the time of takeoff was at 14:34:17 hours (20:34:17 UTC); however, the time of the accident cannot be determined with precision with the evidence collected, although from the information of the flight progress strip it was determined that the helicopter would travel at a speed of 150 knots (278 km/h) and in the electronic flight plan provided to the Air Traffic Controller, the helicopter would travel at a speed of 140 knots (259 km/h).

Making the corresponding operations, it is estimated that the helicopter might have flown:

Approximate distance (NM) [km].	Approximate speed (knots) [km/h]	Approximate flight time (hours)	Approximate UTC time
7.45 [13.8 KM]	**150** [278]	00:02:59	**20:37:16**
7.45 [13.8 KM]	**140** [259]	00:03:12	**20:37:29**
7.45 [13.8 KM]	130 [241]	00:03:26	20:37:43
7.45 [13.8 KM]	120 [222]	00:03:43	20:38:00
7.45 [13.8 KM]	110 [204]	00:04:04	20:38:21
7.45 [13.8 KM]	**100** [185]	00:04:28	**20:38:45**
7.45 [13.8 KM]	**090** [167]	00:04:58	**20:39:15**

Table 1.18.1. Calculations of accident occurrence times.

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There is a two-minute difference between using a speed of 150 knots (278 km/h) and 90 knots (167 km/h), however, because there is no evidence of radar or ELT images at the time of the event, the exact time of the event could not be determined.

Based on the information in the flight log, where the crew recorded the flight time for the different operations, an approximate speed was calculated for the operations carried out during the two days before the accident, considering the approximate distance in a straight line, in the Google Maps system, from which the following speeds were determined:

Date	Logbook Folio	Origin	Destination	Flight time (h)	Distance Km (Miles)	Average speed Km/h
December 22nd, 18	1061	HPW	HAQ	00:04	8 (4.97)	120 (65 kn)
	1061	HAQ	SAI	00:27	107.21 (66.61)	238 (128 kn)
	1061	SAI	MEX	00:05	17.6 (10.93)	211 (114 kn)
	1061	MEX	SAI	00:05	17.6 (10.93)	211 (114 kn)
	1062	SAI	AOC	00:26	35.09 (21.80)	81 (44 kn)
	1062	AOC	PBC	00:10	35.53 (22.07)	213 (115 kn)
December 23rd, 18	1063	PBC	VIR	00:23	23.38 (14.52)	61 (33 kn)
	1063	VIR	APA	00:20	46.55 (28.92)	140 (75 kn)
	1063	APA	PBC	00:14	61.25 (38.05)	262 (141 kn)

Table 1.18.2. Calculation of estimated speeds (average speed of take-off, flight and landing).

Findings from flight speed analysis:
Analyzing the flight time data against the approximate distances to the destinations, there is no way to ensure the speed at which the helicopter was actually traveling, especially since there are no radar video images, no flight data recorder, and neither the exact time of takeoff nor the time of impact with the ground is known.

The estimated speed is an average speed. It is important to note that, in cases where the average speed is below 128 kn (above 114 kn), it is reasonable to assume that the cruising speed and/or maximum speed at one point in the operation was above 128 kn.

Analyzing the flight time data against the approximate distances to the destinations, it can be seen that on the flight from Apan, Hidalgo (APA) to Puebla Airport (PBC), the aircraft operated above the restriction speed of 128 kn, established in the Flight Manual. On other occasions, the calculated average speed was equal to or close enough to the restriction speed to assume that the cruise speed was also above that limit.

At the end of the analysis of the information related to the maintenance of the aircraft, the following written questions were asked to the pilot who was also flying the XA-BON; it was explained to the pilot that, from September 2017 to the day of the accident, there was a recurrence of reports recorded in the flight log of "occasional" course deviations to the right, and the pilot pointed that ***"(...) they were small occasional deviations flying with flight director and their origin was unknown (...)" [sic].***

Additionally, he was asked what actions they took as crew members to compensate for this behavior, since there were reports recorded in the logbook indicating the need to replace the electromechanical linear actuator, mentioning to him that the frequency of replacements increases over time; he revealed that ***"(...) they kept monitoring the flight by avoiding flying at night or in IMC conditions (...)" [sic].***

In addition, he was made aware that in the flight log folio 1043, it was stated that operational tests were performed where the electromechanical linear actuator, installed on September 10th, 2018, was damaged, but at the date of the accident the discrepancy form had not been closed; he stated that ***"(...) these variations were not presented by the machine in a constant manner; that is to say, it could go up to a month without presenting them, in variations of no more than 3 degrees that were controlled in VMC manual mode (...)" [sic].***

Regarding the last discrepancy recorded by the crew in the flight log, he stated that ***"(...) he does not remember the content of the discrepancy since it was recorded by the Captain and he signed it (...)" [sic]****;* he was asked to describe in detail how (pilot and co-pilot) detected in normal flight the operation of the actuator described in the logbook, to which he stated that: ***"(...) they felt sensations of left or right deviation in the controls, for which they proceeded to disengage the flight director and continued the flight in VMC (...)" [sic].***

Finally, he was asked if from December 13th onwards he and the captain of the XA-BON took a briefing or developed any operational procedure to be followed in the case of actuator failure, and he informed that: ***"(...) they did not make a specific briefing of the linear actuator failure since it did not occur frequently (...)" [sic].***

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During the field investigation, the presence of birds (white heron/great egret) was observed in the area of the XA-BON accident, so the possibility that one or more herons had impacted the cockpit or any of the components of the main rotor or its blades and caused the loss of control of the helicopter in flight was analyzed.

1.17.a. Presence of birds in the vicinity of the accident site.

After analyzing the wreckage at the accident site, no evidence was detected that any of the crew members had been hit by a bird or object external to the parts of the helicopter registered as XA-BON; furthermore, there is no evidence of bird remains among the wreckage in the cockpit. Therefore, this hypothesis was ruled out as a possible cause of the accident or as a contributing factor.

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2. ANALYSIS.

2.1. Flight operations

2.1.1. Development of the flight.

On December 13th, 2018, maintenance detected that the roll linear actuator two (SAS2), ***"the roll linear actuator was found damaged. It requires replacement" [sic],*** and according to the interview practiced to the technicians who performed the fault isolation, they indicated to have forgotten to record in the flight and maintenance log, in the Deferred section under MEL, the ATA 22 Auto Flight, 1 Stability Augmentation System, SAS2, category B; it is worth mentioning that said actuator had been installed on September 10th, 2018, in a repaired condition.

The evidence indicates that the representatives of the Operator (pilot and co-pilot), were aware that the SAS2 was intermittently failing and that replacement of the SAS2 roll linear actuator was required, in accordance with the authorized MEL (based on the MMEL edition D) of the air operator, Servicios Aereos del Altiplano, which was due for replacement by December 17th, 2018.

On December 20th, 2018, the technical staff of the Aeronautical Workshop of Rotor Flight Services performed the replacement of the lower half scissor of the swashplate, due to excessive rattling.

On December 22nd, 2018, the helicopter performed 6 operations, with a total duration of 01:21 hours; on December 23rd, 2018, the helicopter performed 3 operations, with a duration of 00:57 hours.

On December 24th, 2018, the helicopter took off at 13:34:12 hours (19:34:12 UTC) from Puebla Airport; at 13:39:22 hours (19:39:22 UTC) the crew notified TWR PBC, the long landing at El Triangulo heliport and that they would be pending for the new departure; however, they actually landed in the yard of a private residence located at the latitude See reference 1 and longitude See reference 1 coordinates.

The helicopter took off from the yard of this residence at 14:34:17 hours (20:34:17 UTC), reporting, ***"... departing the Triangulo (HAQ) via Capital Radio (HUM)" [sic],*** the CTA of TWR PBC provides them with altimeter correction information ***"thirty twenty-seven" [sic],*** and instructs them as follows: ***"call two miles ahead to cross the station" [sic];*** there being no confirmation of the instruction, at 14:35:16 hours (20:35:16 UTC), the CTA of TWR PBC proceeded to call the XA-BON and asked them if they had received the instruction; the XA-BON co-pilot said: ***"... we turned the radio back on..., eh, I did not copy you, now we are, eh..., six point six miles from the Airport and we are going by Capital Radio" [sic],*** the CTA of TWR PBC again provided them with the altimetric correction information and informed that there were no transits, telling them to call when crossing over the station to continue their flight, the XA-BON correctly confirming the information; this was the last communication established between the air traffic services and the XA-BON crew.

Witnesses indicate that they observed the helicopter flying steadily, heard an engine noise and then the helicopter began to "yaw" (witnesses describe this as making small movements in the yaw axis) and then the helicopter turned on its longitudinal axis (roll) and then impacted in an inverted position and nose first into the ground.

The explosives experts, after examining the crash site and the wreckage of the helicopter, indicated that they found no explosives or non-fuel substances that could have exploded inside the crashed aircraft, so the competent Authorities for air accident investigation took control of the crash site and the wreckage of the XA-BON.

It should be noted that the analyses carried out on the helicopter wreckage related to the flight controls recovered at the accident site were exhaustive, although due to the damage caused by the impact and fire, in addition to the absence of flight and voice data recorders, the conclusions herein present the most probable scenario based on the elements available to us during the investigation.

2.1.2. Crew Qualifications
Commander.

2.1.2.1. Mr. See reference 2 [redacted] was the holder of Commercial Helicopter Pilot License number 200601305, valid as of February 16th, 2021, which authorized him to fly an aircraft of this type and weight.

2.1.2.2 He had the ability to operate helicopters as Pilot in Command of Agusta A109S, instruments, multi-engine and RTAR, and was qualified to fly in accordance with the regulations in force on that date.

2.1.2.3. He had an APT psycho-physical fitness certificate without observations or restrictions, was medically fit and had sufficient rest to perform flight operations; he complied with the regulations regarding flight time and period of service.

2.1.2.4. In March 2018, he took the recurrent VFR/IFR course, on A109S equipment, which included Standard and Emergency Procedures on Agusta A109S and A109E equipment. He had sufficient skills and experience to operate helicopters as Pilot in Command of Agusta A109S, instruments, multi-engine and RTAR.

2.1.2.5 According to the communications established with the Puebla Control Tower, the helicopter commander was the pilot flying at the time of the accident.

First Officer.

2.1.2.6. Mr. See reference 2 [redacted] was the holder of Commercial Helicopter Pilot License number 201220887 valid as of September 13th, 2021, which authorized him to crew an aircraft of this type and weight.

2.1.2.7. He had the ability to operate helicopters as Pilot in Command of Agusta A109S, instruments, multi-engine and RTARI level 4, and was qualified to fly, in accordance with current regulations.

2.1.2.8. He had an APT psycho-physical fitness certificate with the observation that he wore glasses for near vision, was medically fit and had sufficient rest to perform flight operations. He complied with the regulations regarding flight time and period of service.

2.1.2.9. In July 2018 he took the Standard and Emergency Procedures course on Agusta A109S equipment, as well as the periodic pilot course on A109S equipment. He had sufficient skills and experience to operate helicopters as Pilot in Command of Agusta A109s, instruments, multi-engine and RTAR.

2.1.2.10. According to the communications established with the Puebla Control Tower, the First Officer of the helicopter was acting as co-pilot and was in charge of communications on the day of the accident.

Technical Maintenance Personnel

The Aeronautical Technical Maintenance Personnel who performed the inspections and corrected discrepancies in the XA-BON helicopter, had the initial and recurrent courses on the A109S equipment, as well as the necessary experience and skills, in accordance with the regulations in force.

Psychological and physiological factors affecting flight personnel.
The investigation detected that maintenance personnel did not remember which roll linear actuator of the SAS2 had an intermittent malfunction.

The pilots had valid medical certificates of aptitude and complied with the medical requirements for Aeronautical Technical Personnel. There were no psychophysical disorders or ailments of human factor that could have contributed to the genesis of the accident; furthermore, there were no factors of personal, family and/or social origin that could have been determinant for the occurrence of the event.

According to the autopsy report, the toxicological analysis and the genetic recognition protocol, it is concluded that no evidence of unauthorized or illegal substances was found.

There is also evidence indicating that the aircraft commander and the co-pilot were aware that the SAS2 roll linear actuator was intermittently failing and that they were looking into the possibility of replacing it, however, they continued to operate the helicopter due to previously acquired flight commitments.

To evaluate the human factor, the SHELL Model was applied, considering the following areas:
- i. Human Resources.
- ii. Procedures.
- iii. Environment.
- iv. Machinery.
- v. Organizational.

i. Human Resources
Crew:
a) It was determined that there was overconfidence on the part of the crew:
- Operating with an automatic flight system (SAS2) with intermittent failure.
- Having made 31 flights totaling 07:55 hours, from December 17th until the day of the accident, being affected by MEL.

b) Loss of situational awareness, due to:
- Indication in the electronic flight plan and ICAO flight plan that the flight would be conducted at a speed of 140 and 150 knots respectively.

Maintenance:
c) The RFS workshop maintenance technicians did not record in the maintenance log that the 22 Auto-flight system, Stability Augmentation System, repair level category "B", was deferred by the MEL authorized to the XA-BON.

ii. Procedures
a) The MMEL revision "E" establishes that when a SAS is inoperative, the Maintenance area must secure and disable the affected SAS.
b) The MMEL, in its revisions "D" and "E", establishes that when a SAS is inoperative, flights must be performed only under VFR rules and adhere to the limitations established in the Flight Manual of the helicopter (flying below 128 knots, among other considerations), the lists indicate that the Autotrim System would not operate.
c) MMEL revisions "D" and "E", in addition to the Flight Manual of the helicopter, establish a restriction to operate an aircraft with an out-of-service SAS, at a maximum speed of 128 knots.

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d) Lack of adherence to the swashplate removal procedures, resulting in a decrease in the clearance between the bar head and the cover, which caused wear; although this does not influence the causing or contributing factors.

iii. Environment

a) Weather conditions are not considered a factor for the occurrence of the accident.

iv. Machine

a) The SAS2 linear actuator of the aircraft presented an intermittent failure, which was detected during the application of the isolation procedure by an avionics technician, without placing any physical restriction (dropping the circuit breakers, placing a guard in the cockpit and placing an out of service label); the helicopter crew decided to continue operating the helicopter without considering any of the restrictions indicated in the Flight Manual (maximum speed of 128 knots and knowing that the Autotrim System was not going to be available).

v. Organization

a) The operator did not have enough personnel to supervise the operation of the aircraft, considering that the XA-BON landed in a place different from the one stated in the electronic flight plan (courtyard of a private residence).
b) They did not update the MEL of the XA-BON according to the MMEL revision "E".
c) Maintenance and operations personnel were applying an authorized MEL that was technically outdated.
d) The Aeronautical Authority did not detect that the MEL of the operator was outdated and granted them the renewal of the Air Services Operator Certificate in December 2018, days before the occurrence of the accident.

2.1.3. Operational procedures.

The AFCS (Automatic Flight Control System) of the A109S helicopter works in conjunction with the Attitude and Direction System, the Yaw Rate Turn System, the Flight Director System and are the means to automatically control the flight.

The AFCS consists of two independent subsystems, controlled by a common control panel; each system consists of a computer, three linear actuators for SAS 1, two linear actuators for SAS 2 and two synchronous position transmitters (roll and pitch synchro-transmitters); the linear actuators are interconnected through a mixer unit with the hydraulic servo-actuators of the cyclic stick, from which they are connected to the swashplate and from which the pitch change rods are connected to the main rotor blades; the yaw linear actuator is connected to the hydraulic servo-actuator of the tail rotor.

The linear actuators are installed in series, in linkage control, and therefore operate without changing the position of the cyclic stick and pedals. Synchronous transmitters detect the rotation of the control to which they are connected by means of links. The nominal rotation of these is ± 30º.

The automatic stabilization system has two modes of operation: Stability Augmentation System (SAS) and Attitude Hold Mode (ATTD HOLD).

In SAS mode, each automatic stabilization channel works as a damping system to stabilize the helicopter when its normal flight configuration is changed by external forces (turbulence, updrafts/downdrafts, sudden changes of

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path). In this mode, the operation of the automatic stabilization system does not interfere with the attitude changes of the helicopter, when commanded by the pilot.

In ATT HOLD mode, each automatic stabilization channel is capable of maintaining the flight comfort attitude, providing the pilot with limited ability to take the cyclic stick without holding it with his hands (hands-off flying). The pilot has the possibility to momentarily control the helicopter by activating the beeper trim selector switch located on the cyclic stick grip.

To allow automatic flight path control, the stability augmentation system (SAS) is coupled to the flight director system. In this mode, the computers automatically steer the helicopter along the longitudinal and transverse axes, to follow the commands of the FD (Flight Director), which are displayed on the EADI (Electronic Attitude Display Indicator).

When engaged, the Autotrim System provides power to the lateral and longitudinal cyclic magnetic brakes at any time, when the pitch and roll linear actuators have exceeded 30% of their travel from the center position. This action restores full authority to the actuators and relieves the pilot from continuous monitoring. The re-adjustment operation occurs 3 seconds after both linear actuators reach 30% of their travel from the center when both actuators are moving in the same direction, in extension or retraction.

Note: Re-adjustment of the yaw axis is required. The auto-trim system is operational when both automatic stabilization systems are in COUPLED mode. The auto-trim action can be interrupted by disengaging either auto-stabilization system, applying force to the cyclic stick or turning the F-TRIM (Force Trim) switch to Off.

The helicopter has a Flight Director (FD) system, which processes navigation and attitude information by means of an external sensor and provides steering commands in the pitch and roll axes, which are displayed on the EADI and fed to the automatic stabilization system for automatic en route flight control.

The FD system works in conjunction with the VOR/LOC, gyrocompass, vertical gyroscope, radio altimeter and automatic stabilization systems. The FD system consists primarily of a computer, an altitude sensor, an airspeed sensor, a control panel and a collective lever synchro-transmitter. The FD computer provides all pitch, roll and collective axis commands to the EADI and the automatic stabilization system computer.

The FD control panel allows the pilot to select various flight modes of the system. The control panel has illuminated push button switches to select the mode of operation of the FD in standby, on the bank axis, or on the pitch axis. When an operating mode is selected, it is shown by the illumination of the push button switch. The synchronous transmitter (synchro-transmitter) provides collective lever position information for use in the FD computer in GA (Go Around) mode. The MSTR AVNX switch controls the circuit breakers.

When the helicopter is in flight and it appears that a helipilot is operational (SAS1 or 2) the flight manual of the helicopter restricts its operation to visual flight rules and that the flight be

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performed up to a speed of 128 KIAS and/or a rate of climb of 1,000 ft/min, above 500 ft above the ground.

The emergency procedure indicates that with the FD (Flight director) engaged, after a SAS failure or an ATT mode failure, the AUTOTRIM system function becomes inoperative.

Without the FD engaged, the AUTOTRIM System function is always inoperative; in these conditions it is recommended that the pilot fly by checking the position on the API (Auto pilot indicator) or fly disengaged, due to the reduced authority of the system.

Note: HELPILOT indicators normally refer to SAS1. When SAS1 is switched to the Off position, the HELPILOT indicators will automatically change to SAS2.

Section 3, "Emergency procedure" of the Agusta model A109S helicopter flight manual (Doc. No. 109G0040A013), states that when it is in flight and there is a functional failure of the SAS, it must be first identified which SAS has the failure and confirm that the switch of the affected SAS has not been tripped; then, the affected SAS must be reset through its switch and the caution message must be verified; if it disappeared when following the procedure, the flight can continue. When the caution message remains on the display, it must be confirmed that the affected SAS is functionally in the OFF position and continue with the flight with an operational SAS with the restrictions indicated in point 1.6.7.1. of this document.

The following consideration was taken from Section 3, "Emergency procedure" of the A109S Helicopter Flight Manual (Doc No. 109G0040A013): When in the flight phase the failure of vertical turn 1 (or 2) occurs, it is necessary to identify which vertical turn failed, which will also be shown in the PFD (Primary Flight Display); any failure of vertical turn 1 (or 2) is associated to SAS1 (or 2), so it will automatically disengage. In such a case, it should be verified that the vertical turn circuit breaker has not been tripped, and the instrument should be left in standby (STDBY - Stand By).

It shall be confirmed that the affected SAS1 (or SAS2) is disabled, i.e., set in the OFF position; if it was displayed that the functional failure and the caution message are coming from the VG1, the pilot shall press the ATT REV button to revert the EFIS1 display to VG2; in case it is the VG2 that presents the failure, the co-pilot shall press the ATT REV button to revert the EFIS2 display to VG1. In both situations the flight can be continued with an operational SAS, with the restrictions set by the manufacturer, as indicated in point 1.6.7.1. of this document.

The helicopter manufacturer indicates that, during flight, the operation of the Helipilot system may malfunction and pilot intervention will be required. These malfunctions are described below:

a) Repeated alterations during the operation of the Helipilot in pitch, roll, or yaw. First of all, the pilot needs to re-trim the helicopter constantly due to pitch, roll or yaw alteration. He should observe the Helipilot Indicators (API), helicopter attitude/rate and ADI[33]s (normal and standby) to identify the affected system.

[33] Attitude Data Indicator

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Note: The SAS2 pitch and roll actuators can be observed by pressing the SAS2 monitor switch on the Helipilot panel; finally, the failing system will be disengaged and the flight can continue with an operational SAS, with the restrictions set by the manufacturer, as indicated in point 1.6.7.1 of this document.

b) Malfunction - oscillations
In this scenario, the power (if possible) and speed should be reduced to 128 KIAS maximum, the Helipilot indicators (API), the helicopter attitude/rate indicator and the ADI's (normal and standby) should be observed; to identify the affected system, the corresponding SAS should be turned off. If the oscillations cease, the flight should be continued with an operational SAS, with the restrictions set by the manufacturer, as indicated in point 1.6.7.1. of this document. If the oscillations do not cease, both SAS must be turned ON and one of them must be disengaged. If the oscillations continue in the yaw axis, the SAS1 switch must be turned OFF and the SAS2 switch must be turned ON.

Note: the position of the SAS2 pitch and roll actuators can be observed by pressing the SAS2 monitor switch on the Helipilot panel. The flight can be continued with an operational SAS, with the restrictions set by the manufacturer, as indicated in point 1.6.7.1. of this document.

There is a Warning that states: Do not attempt to land while there is a malfunction - oscillatory.

Findings:
It should be noted that a pilot flying in manual mode, i.e., with his hands on the flight controls, might be able to compensate for a sudden uncommanded roll caused by the simultaneous, uncommanded (hard over) extension of both linear actuators.

2.1.4. Meteorological conditions.
We analyzed information recorded in the Ordinary Aeronautical Meteorological Report (METAR) issued on December 24th, 2018 at 20:43 UTC (14:43 hours) by SENEAM at the Puebla station, in which meteorological observations indicated the presence of 180° winds, with an intensity of 12 knots (22 km/h), visibility of 12 statute miles (20 km), clouds at 22,000 feet, ambient temperature of 21°C and 0°C dew point temperature; these meteorological conditions are considered stable to perform an operation under visual flight rules.

These conditions are not considered a contributing factor for the occurrence of the accident.

2.1.5. Communications.
The radio communications established by the XA-BON crew were analyzed, observing a normal aeronautical phraseology with the Puebla Tower air traffic services. The instructions and the confirmation of information were carried out in an adequate manner, with good intensity.

At 13:34:12 hours (19:34:12 UTC) the helicopter took off from the hangar platform of Servicios Aereos el Altiplano at Puebla Airport; at 13:39:22 hours (19:39:22 UTC) the XA-BON reported that it was performing a long landing to El Triangulo heliport; that is, it covered a distance of approximately 8.53 NM in a time of 00:05:10 hours and making the pertinent calculations an approximate speed of 113 knots was obtained, which is appropriate, according to the maximum speed restriction of 128 knots indicated in the Flight Manual, when a linear actuator is out of service.

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At 14:34:17 hours (20:34:17 UTC) the XA-BON reported that they were departing from the El Triangulo heliport with destination to Radio Capital in Mexico City. Puebla Tower provided the altimetric correction and instructed them to call two miles before crossing the station; at 14:35:20 hours (20:35:20 UTC) the XA-BON reported at 6.6 NM from the VOR PBC, that is, in 00:01:03 hours it covered a distance of 3.37 NM. According to the calculations, the helicopter was going at an approximate speed of 192 knots, however, this travel speed is not operationally reasonable; therefore, it was not possible to determine the travel using the indicated times.

Based on communications evidence, the approximate time of the event was estimated, but cannot be determined due to the lack of radar video images and emergency locator transmitter (ELT) signal.

2.1.5.1. Inspection of radiocommunications audio.
With the help of software from the manufacturer of the helicopter, we were able to identify the rotation frequency close to 1’820 Hz (which corresponds to the coupling between the Gleason pinion and the gearbox of the main transmission housing) and possibly a second harmonic that is compatible with that of the Planet Gear, 1’625 Hz; both referred to 100% of the main rotor rotation speed. No other frequencies could be identified in the audio file.

At minute 00:14:486, there is no voice or evidence of helicopter identification, this transmission lasts approximately 200 msec. The software that performs the spectrum analysis was able to identify a frequency of around 1’820 Hz that seemed to fluctuate slightly in a range between 1’820 Hz and 1’775 Hz. This frequency of 1’775 Hz is compatible with a rotational speed of approximately 98%; this one being the last transmission that we have in the audio file, it is possible to determine that the XA-BON did not show any unusual frequency behavior during the communications established with the Air Traffic Services.

2.1.6. Inspection of warning lights (MW) and caution lights (MC).
Among the wreckage of the helicopter, the two Master Warning (MW) and two Master Caution (MC) lights were located and sent to laboratories where the corresponding tests were performed to determine whether or not the bulbs were on at the time of the accident.

Test results showed that the 2 master warning light panels and 2 caution light panels were on at the time of impact.

The Master Warning and Master Caution lights could have activated by conditions such as ROTOR HIGH, ROTOR LOW, XMSN OIL PRES, etc., or due to possible extreme attitudes of the helicopter in the moments prior to impact.

2.2. Helicopter.

2.2.1. Helicopter maintenance.
All available records and history were evaluated by RFS and SAA, which indicate that the last two flight and maintenance logs of the XA-BON were on board the aircraft and were destroyed by fire; according to what was observed in other maintenance records, up to October 08th, 2018, these indicate that the helicopter had received scheduled maintenance in accordance with the times and services indicated in the regulations and what was established in this regard by the manufacturer.

In the maintenance records it is noted that: Occasionally, the Aeronautical Technical Staff of the RFS workshop does not include the inspection results in their work orders; some maintenance release tags in the logbook do not make reference to the complementary test documentation and do not contain all the information of the components; there are also discrepancy forms that indicate the opening date of these, but much time elapses for their closure, as is the case of discrepancies 21/2018 and 30/2018, both related to the roll linear actuator of the SAS2. There is also no evidence that, in the fields intended for that purpose in the flight and maintenance log, they have deferred by MEL the ATA 22 Auto Flight, 1 Stability Augmentation System (SAS2), category B. Finally, there is evidence that some work orders were not fill in, or all the spaces required by the work order to fill in specific data were crossed-out.

The aircraft had a current airworthiness certificate number 20181252, issued on September 21st, 2018 and, according to the evidence, its airworthiness was maintained in accordance with the regulations, until the time they failed to adhere to the XA-BON MEL procedures.

On October 19th, 2017, maintenance personnel removed the roll linear actuator from the SAS2 due to ***"SUDDEN COURSE CHANGE WITH FLIGHT DIRECTOR ENGAGED", S/N*** see r 3-***506*** and installed the linear actuator ***S/N*** see r 3-***118;*** the discrepancy was opened on September 18th, 2017, elapsing 31 days for component change and discrepancy closure, but they did not defer the SAS2 per the current MEL of the aircraft.

On June 25th, 2018, maintenance detects that the SAS2 roll linear actuator required replacement due to: ***"SUDDEN COURSE CHANGE WITH FLIGHT DIRECTOR ENGAGED",*** so on July 4th, 2018, they removed the SAS2 roll actuator ***S/N*** see r 3-***118*** and installed the SAS2 roll actuator ***S/N*** see r 3-***551***, taking 9 days to change the component and close the discrepancy; they also did not defer the SAS2 per the current MEL of the helicopter.

The SAS2 roll actuator ***S/N*** see r 3-***118*** was repaired by the Precision Accessories & Instruments (PHP-PAL) workshop and on September 10th, 2018, RFS technicians removed the roll linear actuator **S/N** see r 3-***551*** and installed the SAS2 roll linear actuator ***S/N*** see r 3-***118***, and this was the last time this component was removed.

On December 13th, 2018, maintenance generated discrepancy form 21/2018 for the crew logbook report of ***"SUDDEN COURSE CHANGE WITH FLIGHT DIRECTOR ENGAGED",*** performing the corresponding fault isolation, finding damaged the right roll linear actuator ***S/N*** see r 3-***118*** of the SAS2, elapsing 11 days from the opening of the discrepancy for the change of the component, remaining open until the day of the accident.

In the two SAS2 roll linear actuator changes, there are no records in the flight and maintenance log that the SAS2 was deferred by the current MEL of the aircraft.

The maintenance technicians of the Rotor Flight Services workshop forgot to record in the flight and maintenance log (folio 1043 of December 8th, 2018), the deferred "ATA 22 Auto Flight, 1 Stability Augmentation System (SAS2)", repair category "B" according to the MEL of the XA-BON, based on which the change of the roll linear actuator of the SAS2 should have been performed before December 17th, 2018.

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Also, according to MMEL revision "E", ATA 22 Auto Flight, 1 Stability Augmentation System (SAS2), repair category "C", indicates that the replacement of the SAS2 roll linear actuator S/N 99124118 should have been performed before December 24th, 2018.
According to maintenance records, the aircraft at the time of dispatch for the flight had a SAS2 roll linear actuator, which maintenance identified as damaged and in need of replacement; however, this SAS2 roll linear actuator, remained installed on the helicopter until the flight on the day of the accident.

There was intermittent malfunction of the roll linear actuator (SAS2) according to the maintenance records, contributing to the occurrence of the accident.

The aircraft operator should have incorporated Revision "E" of the MMEL of EASA into the MEL of the XA-BON within a reasonable time and submitted the modifications to the Aeronautical Authority for authorization.

2.2.2. Findings of the inspection

During the inspection performed in the laboratories it was determined that: The rotating scissor, main rotor controls, main rotor hub, hydraulic servo-actuators, thruster systems, main gearbox, combination gearbox, 90° gearbox, tail rotor controls and associated components, were not found to have mechanical failures or anomalies that would have prevented or limited the normal operation of the helicopter; all observed fractures present in the components examined for analysis had signs of overstress failure such as 45° angles, due to impact.

The aircraft was completely destroyed by the impact forces and post-impact fire.

The main and tail rotor blades showed damage indicating that the engines were running at the time of impact. The blades showed chordwise and torsional damage, indicating that they were in rotation at the time of impact.

2.2.2.1. Electromechanical linear actuators

When the aircraft had a total time of 74.1 hours, the yaw actuator was replaced for the first and only time, and the roll linear actuator number two was replaced on two occasions starting in September 2017.

2.2.3.1. Design location of pitch and roll actuators

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The roll 1 (SAS1), pitch 1 (SAS1) and pitch 2 (SAS2) linear actuators were never removed from the helicopter, i.e., they were installed in the helicopter since its manufacture.

Linear actuators, according to the maintenance manual, are considered "on condition" components, i.e., they do not have a life limit for replacement and are only removed for required repair when a failure is detected.

Linear actuator on the roll axis of the SAS2.
On October 19th, 2017, the maintenance personnel, after having performed the corresponding fault isolation, removed the roll linear actuator from the SAS2, ***S/N*** see r 3***-506*** and installed the linear actuator ***S/N*** see r 3***-118***, due to a report from the pilots who stated that the helicopter deviated from course to the left occasionally, with the flight director engaged; the discrepancy was opened by them on September 18th, 2017. There is no record in the flight and maintenance log, that the SAS2 was deferred by MEL and 31 days elapsed for the component change.

On June 25th, 2018, RFS maintenance personnel follows up on the crew report given that they notified: ***"SUDDEN COURSE CHANGE WITH FLIGHT DIRECTOR ENGAGED" [sic],*** the technicians performed the corresponding fault isolation and detected that the SAS2 roll linear actuator was damaged so, on July 4th, 2018, they removed the SAS2 roll linear actuator ***S/N*** see r 3***-118*** and installed the SAS2 roll linear actuator ***S/N*** see r 3***-551***; there is no record in the flight and maintenance log of the ATA 22 Auto Flight, 1 Stability Augmentation System (SAS2), repair category "B" by MEL, being deferred, although 9 days elapsed for them to perform the component replacement.

It should be noted that, in the month of May 2018, EASA issued revision "E" of the MMEL, which indicates that with a fault such as the one detected, the affected SAS should be put in inoperative status, deactivating the system by pulling the corresponding circuit breakers and placing a card indicating that it was out of service.

The SAS2 roll linear actuator ***S/N*** see r 3***-118*** was sent for repair to the Precision Accessories & Instruments (PHP-PAL) workshop in June 2018; the PHP-PAL workshop, once the applicable repair (Overhaul) was performed, generated the FAA 8130-3 form, certifying that said component was ready to be used again. On September 10th, 2018, RFS technicians received the SAS2 roll linear actuator ***S/N*** see r 3***-118*** and proceeded to install it on the helicopter, closing discrepancy number 09/2018, dated June 26th, 2018.

On December 13th, 2018, the RFS maintenance area generated discrepancy 21/2018 per logbook report on folio 1043, dated December 08th, 2018, clarifying that the logbook containing this folio, plus other XA-BON documents, were destroyed by the fire that occurred after the accident.

The technical personnel who serviced this report indicated that the report of the crew indicated: ***a slight course deviation,*** performing the corresponding fault isolation and finding the SAS2 roll linear actuator damaged.

According to the MEL authorized by the SSA air operator, the change of the component was limited to 3 days, not counting the day the failure was detected, so the component should have been replaced at the latest, on December 16th, 2018, leaving open discrepancy 21/2018.

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2.2.2.2 Inspection of electromechanical linear actuators.

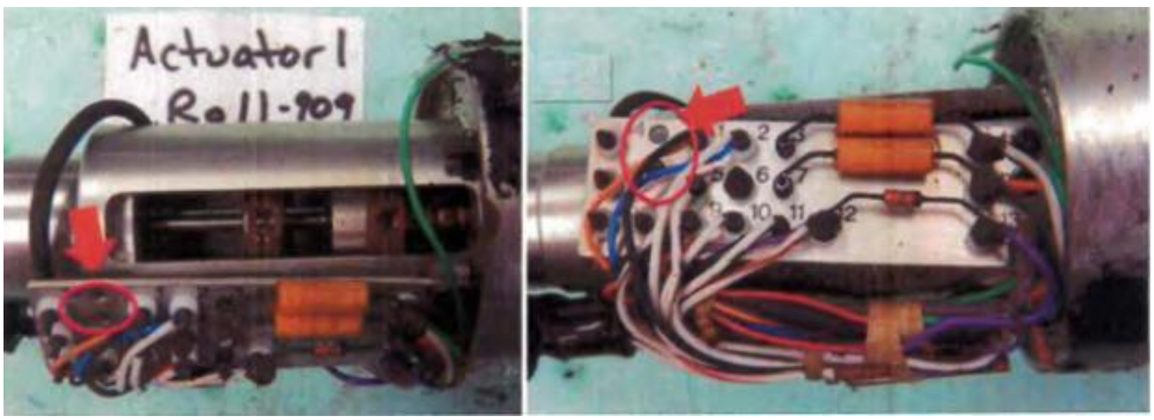
The results of the destructive inspection of the 5 electromechanical linear actuators, 2 for roll, 2 for pitch, and 1 for yaw, yielded the following most significant findings:

SAS1 roll linear actuator, left position. (P/N 4012373-909, S/N see r 3-409)

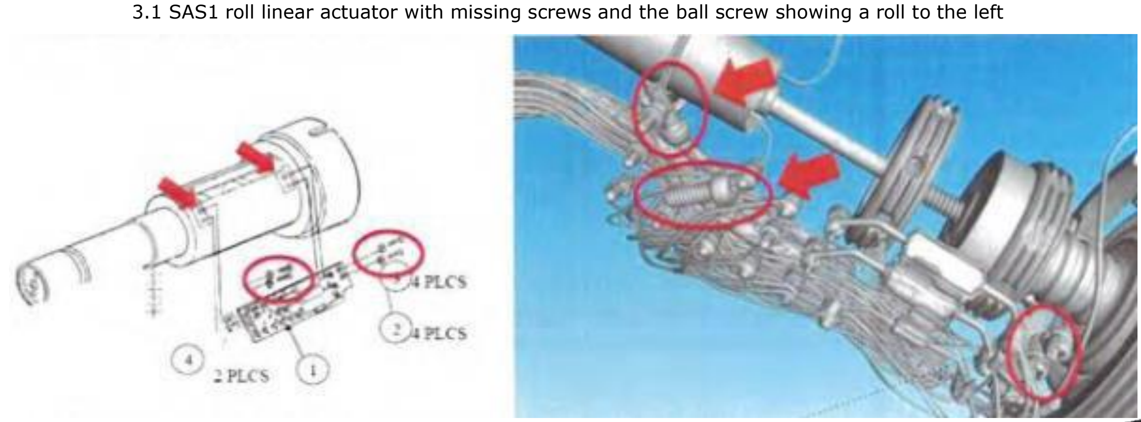
a. The travel stop (attached to the ball screw shaft) was next to the extension side travel adjustment ring. The actuator extension is related to a leftward tilt.
b. A metallic residue was found on the inside diameter of the casing. The depth of the part from the larger diameter end (where the long rod end is located) was approximately 2.165 inches.
c. Two of the four screws holding the electronic tablet to the bracket were found loose and the electronics board unattached at that end, and remained partially connected to the actuator body at the opposite end. The screws found loose inside the body had their washer, however, one washer was not found.
d. During the cutting of the tie wrap holding the wires together, a piece of black wire was found separated from the rest of the wires; one end had the appearance of a hook, which should have been connected to terminal 11.

Analysis of a loose screw touching the electronics board terminals

The SAS1 roll linear actuator (P/N 4012373-909, **S/N** see r 3-409) had 2 of the 4 retaining screws that hold the electronics board to the actuator body completely unscrewed and moved freely between the metal actuator body and the LVDT housing.



3.1 SAS1 roll linear actuator with missing screws and the ball screw showing a roll to the left



2.2.2.2.2a CT scan image of the SAS1 roll linear actuator with the screws detached

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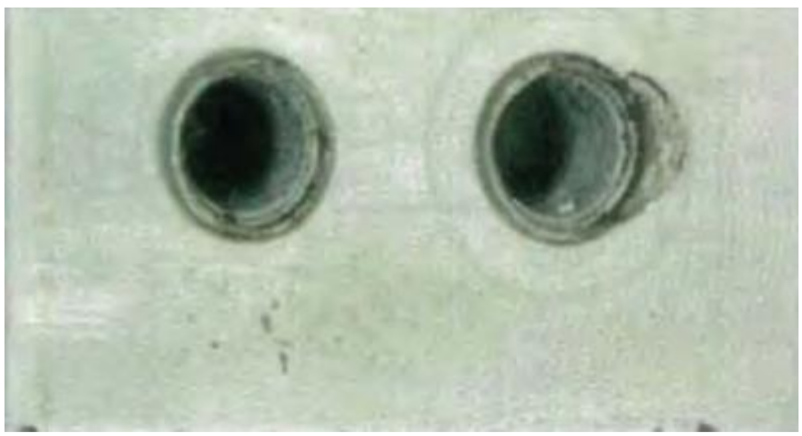
The study focused on how the behavior of the helicopter is affected when there is a possible contact between one of the two screws and one of the terminals of the electronics board. The result was as follows:

From Attachment E, paragraph 3 it is clear that:

- Condition No. 2:
  Describes the contact of one of the screws between terminal 1 and terminal 2 on the electronics board of the linear actuator. Result: the linear actuator extends (roll to the left) and reaches its full travel stroke in less than 1 second.
- Condition No. 5:
  Contact between terminal 9 and terminal 10 on the actuator electronics board. Result: there is a loss of 26 VAC which causes the SAS to disengage and the linear actuator brake to activate.
- Conditions No. 6:
  Contact between terminal 10 and ground terminal. Result: there is a loss of 26 VAC which causes the SAS to disengage and the linear actuator brake to activate.

Laboratory examination of the bolts and holes in the housing of the SAS1 roll linear actuator showed that two strings were damaged.

In one of the holes in the casing it was detected that the threading showed damage near the outer edge of the hole with a thread impression.



2.2.2.2.b Close-up of damage to a near-thread impression

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The remaining hole strings showed no evidence of being affected by the screw string. The contours of the four holes in the electronics board had elliptical marks, indicating that there was contact of the washer with the electronics board.

Measurements were taken of the electronics board; the spacer and the washer showed a total thickness of 0.120 in. The length of the hole in the actuator was measured to be approximately 0.173 in.

The above evidenced that only 2 to 3 threads made contact with their threaded hole in the actuator body, after installation of the screws found loose. The threads of the two screws which were found loose inside the actuator housing had metallic residues.

It was not possible to determine when the bolts came loose in this roll linear actuator, since in its history it does not have any maintenance work or previous failure; it should be noted that in Mexico no maintenance workshop has the authorization, or the capacity, to perform work on this type of actuators; only the manufacturer, and in if applicable, a workshop authorized by the Federal Aviation Administration of the United States (FAA), could perform certain maintenance or repair services, pointing out, to emphasize what is relevant, that this linear actuator was not the one that presented the failure; that is to say, that during the failure isolation tests it did not present evidence of malfunction.

It is also important to note that fault isolation tests are activities performed while the helicopter is on the ground and secured with its chocks.

Since 2017, the XA-BON crew noted that while flying it would occasionally veer off course, i.e., this condition did not occur on every flight.

Honeywell indicated that it reviewed more than 5,000 records of repairs performed on linear actuators at Honeywell and Otto facilities, and found only one record where the personnel performing the repair noted in their documentation ***"screws missing - FPN: 2504349-52"*** and ***"washers, locking missing - PFN: 0164-2"***; however, they did not specify in their report whether the screws were found inside the linear actuator housing or were simply not installed.

It should be emphasized that this roll linear actuator was installed when it was new on the helicopter and was never removed. Also, the "static" inspections performed by RFS technical personnel on these systems are not sufficient to show evidence of loose bolts, lack of continuity or any other type of failure. The SAS1 roll linear actuator had no record of previous malfunction.

SAS2 roll linear actuator, right position. (P/N 4012373-909 S/N see r 3-118)

a. A repair tag was found on the actuator housing, it was partially legible, and it read:

Precision Accessory and Instruments
A PAG Company
Atlanta 404-767-5900
Repair Station ZV4R714M
www.precisionaccessories.com

b. The stroke stop screws were next to the stroke adjustment ring on the extension side. The extension of the linear actuator correlates with a roll input to the left.
c. The electronics board remained connected to the actuator body.
d. The brake cable was broken where the wiring is located. The purple cable of the brake was not connected to the electronics board at port 12, but the port was covered with sealant.
e. A continuity test was performed on the motor wiring, which was open.
f. The brake was retained with the front housing. Thermally degraded grease was observed on the inside diameter of the brake housing and ball screw.
g. The ball nut could be moved with hand force. Rotation of the ball nut exhibited roughness, but did not evidence binding. The ball screw was able to complete its stroke between the adjustment rings.

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This linear actuator showed the ball screw extended. The extension of the actuator correlates with a roll input to the left.

Due to the internal damage present in the SAS2 roll linear actuator, it was not possible to determine the reason for the intermittent fault that the technicians detected during the fault isolation performed on December 13th, 2018, which was recorded in discrepancy 21/2018, nor can it be asserted what caused its extension at the time of the failure of the SAS1 roll linear actuator.

SAS1 Pitch Linear Actuator, (P/N 4012373-908 S/N see 3-333)

a. The stop stroke was next to the adjustment ring on the retraction side, which corresponds to nose down.
b. The ball screw nut could be turned by hand on the screw, but there was evidence that it was stuck initially. Soot was observed on the visible part of the ball screw. The ball bearing in the front casing could not be turned.
c. The rotor had superficial damage with the appearance of corrosion.
d. The rear casing bearing could be rotated, but showed signs of roughness.

SAS2 Pitch Linear Actuator, (P/N 4012373-908 S/N see 3-158)

a. The stroke stop was found next to the adjustment ring on the retraction side; this corresponds to nose down.
b. The ball screw nut could be turned by hand, with no evidence of binding. The ball screw nut had evidence of reddish, thermally degraded grease. The bearing in the front housing could be turned freely.

SAS1 Yaw Linear Actuator, (P/N 4012373-905 S/N see 3-433)

a. The surfaces of the actuator body and internal components showed thermal damage. Soot was observed on the surfaces of the internal components.
b. The electronics board was present, but some of the terminals had separated from the board. Continuity checks were not performed due to thermal damage to the circuit board as well as to the wires.
c. The stroke stop was approximately halfway between the two adjustment rings.

Findings.

The roll linear actuators of the SAS1 and the SAS2 were found to be in full extension.
The pitch linear actuators of the SAS1 and the SAS2 were found to be in full retraction.
The yaw linear actuator of the SAS1 was found to be in the intermediate (center) position.

It should be noted that, if the RFM (Flight Manual) limitations apply with respect to an operational Helipilot, the disconnection of the Helipilot or the roll linear actuator in a "hardover" condition does not result in a loss of in-flight control of the Helicopter. Even if the two SAS are not working, the aircraft may continue with the flight, only taking into account the restrictions established in the Flight Manual and the MEL.

The operational restrictions set forth in the MEL of SAA indicated that flights should only be planned in VFR conditions and be attentive to flight development (indicated speed up to 128 knots and/or rate of climb of 1,000 ft/min, flying above 500 ft above the ground) or manually in all other conditions.

The results of the analysis and experimental tests, when a loose screw is moving on the surface of the electronics board, highlighted that, out of 9 failure modes, 2 of them result in

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the loss of the ability of the Helipilot to control the linear actuator presenting the fault (i.e., "hardover") or disconnection of the AFCS.

2.2.2.3. Mast Vibration Absorber (MVA).
The beanie of the MVA showed signs of rubbing on the inner surface. During disassembly of the beanie, evidence of improper installation was observed because when the swashplate is installed without removing the MVA assembly, the clearance between the rod head and the beanie is reduced causing the friction found on the inside of the cover.

The holes of the fastener screw holding the beanie show no evidence of fatigue fractures; they all are consistent with overstressing. The beanie of the MVA contained an arc-shaped mark inside, compatible with the impact area of the MVA.

After an exhaustive analysis of the MVA (Mass Vibration Absorber) beanie, it showed evidence that the mass became detached upon impact with the ground; the MVA (Mast Vibration Absorber) is not an aircraft flight control essential for flight. The strings of the shaft in which the mass is housed showed that the mass was installed contained by the thread and the corresponding safety brake.

The mass or counterweight was not located at the site of the accident, although it was searched by personnel from SEDENA, DGAC, Attorney General's Office of the State of Puebla, in a diameter of 1 NM (1.85 km); it should be noted that the authorities were present at the site of the accident approximately 20 minutes after the accident occurred.

2.2.2.4. Engines
2.2.2.4.1. Position engine number one (S/N BH0434).
According to the data provided by RFS, the engine received the 200-hour service, performed on November 28th, 2018. The stalls reported by the crew in the maintenance log were due to a dirty condition in the internal components of the engine caused by insufficient compressor washing, which was confirmed after the corresponding washing was performed; the verifications performed indicated that the engine recovered the power margin and returned to normal operation. There were no further reports recorded in the maintenance log, in this regard, after April 23rd, 2018.

The engine exhibited deformation due to the impact, but no pre-accident anomalies were detected. The compressor impeller blades were all present and showed evidence of operation at the time of impact; damage to the leading edge was in the direction opposite to rotation. The compressor turbine blades were all present and showed signs of friction at the tip. The power turbine (PT) blades were also present and showed signs of friction at the tip. The power turbine (PT) stage disc rubbed against the stator section of the PT. The PT shaft fractured from bearing number 3 due to overloading and presents a 45-degree angle as a result of the impact. This caused the power turbine shaft to rub against the compressor turbine and compressor impeller bores.

Based on the results of the disassembly of the engine or its accessories from the investigation, there are no findings that would have prevented normal operation or indicated a problem prior to impact. Based on the investigation of the engine, it is concluded that the engine was producing power at the time of impact.

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2.2.2.4.2. Position engine number two (S/N BH0499).

According to data provided by RFS, the engine received the 200-hour service and also showed significant damage due to the impact, but did not reveal any pre-accident anomalies. The compressor impeller blades were all present and showed evidence of running at the time of impact, due to damage to the leading edge in the direction opposite to rotation. The compressor turbine blades were all present and showed signs of friction at the tip. The power turbine blades were also present, however, they showed signs of friction at the tip. The power turbine shaft fractured at bearing number 3 due to overloading and exhibited a 45-degree angle as a result of the impact. This caused the power turbine shaft to rub on the compressor turbine and compressor impeller bores.

Findings.

Based on the findings made during the disassembly of the engines, it was determined that they showed damage indicating that they were in operation at the time of impact with the ground, which can be seen on the blades of the high turbine, the impeller and the compressor.

The shafts of the power turbines of both engines show similar evidence of rotation; furthermore, the power lever of both FMMs (Fuel Management Module) was in the maximum acceleration position, therefore, it was determined from both indications that there was no power asymmetry in the engines.

Based on the results of the disassembly of the engine or its accessories from the investigation, there are no findings that would have prevented normal operation or indicated a problem prior to impact. Based on the investigation of the engine, it is concluded that the engine was producing power at the time of impact.

2.2.2.5. Non-volatile memory components.

At the accident site, electronic components with non-volatile memory were recovered; two of them related to the engines, which are listed below:

Engine 1	Engine 2	State
1 DCU (Data Collection Unit).	1 DCU (Data Collection Unit).	Destroyed by impact and fire, the opening was held in Safran, Canada, (March 26th, 2019).
1 EEC (Electronic Engine Control).	1 EEC (Electronic Engine Control).	Destroyed by impact and fire, opening held in Collins, USA (April 18th, 2019)

The Data Acquisition Unit (DAU), which is also a non-volatile memory, was located at the accident site and subjected to destructive testing.

Findings.

The five electronic components with non-volatile memory (2 DCU's, 2 EEC's and 1 DAU), were damaged by fire exposure; all electronic components were detached from their electronics boards, including the non-volatile memory (NVM) chips. The NVM "chips" were recovered inside their respective component housings, cleaned, and when the memories were placed in the reader and action was initiated to extract the data, the reader showed an error message, indicative of no response from the NVMs. Multiple attempts were made, but

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the same results were obtained. Due to the extreme heat exposure, it was determined that the NVM components were totally damaged and as a result, the data stored in these units was permanently lost.

2.2.2.6. Engine Control Lever (ECL).
The engine control levers were found to be in the MAX (maximum) throttle position and upon disassembly and placement of the brackets connecting the worm gear to the levers, they were found to be in a position consistent with the indication of the lever in the FLIGHT (FLT) position. The MAX position on the engine control levers is consistent with the moment when the helicopter impacted the ground in an inverted position, when they were moved to the full throttle position.

2.2.2.7. Main Rotor Hydraulic Servo Actuators (MRA).
The three main rotor servo actuators remained attached to the fixed swashplate; the three servo actuator uprights were fractured; the three input rods remained connected to the servo input linkage, but the input rod tubes were fractured and separated from their rods ends. The fractures showed similarity to each other and were consistent with the mechanics of ground impact.

Findings.
The three servo actuators (Blue, Red and Yellow) were removed from the upper case and the fixed swashplate for inspection by CT scan. Based on the findings, these three components were opened and the CT images confirmed that "there were no internal failures of these components".

2.2.2.8. Hydraulic pumps.
From the inspection performed on the left and right hydraulic pumps, the evidence showed no internal damage; only the right pump swashplate housing exhibited a fracture that grew longitudinally (on the axis of rotation). The fracture was observed on both the outer and inner surfaces of the housing; however, the drive shaft was able to rotate without evidence of binding. It was therefore concluded that both hydraulic pumps were working normally at the time of the accident.

2.2.3. Aircraft Performance.
Based on the evidence obtained in the field investigation, in the maintenance history, after analyzing the mechanics of the impact and fire, and assessing the witness statements, it was concluded that it was feasible to focus the investigation on only 6 possible scenarios that could have caused the loss of control in flight of the helicopter related to a mechanical failure.

The methodology to determine which of the 6 proposed scenarios were involved in the accident consisted of inspecting all the available mechanical components that involve the systems inherent to the scenarios mentioned below, as well as their components.

These 6 study scenarios were:

1. Failure to transmit power to the main rotor head.
2. Failure to transmit power to the tail rotor head.

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3. Failure to provide lift to the rotorcraft.
4. Failure to provide anti-torque thrust.
5. **Both linear actuators driven in simultaneous hardover in pitch or roll axis.**
6. Loss of hydraulic power in both flight control circuits.

The investigation focused on the automatic flight system of the helicopter, scenario ***5*** **Both linear actuators driven hardover simultaneous in pitch or roll axis,** with special interest in the electromechanical linear actuators, so the destructive inspection of the 5 linear actuators was coordinated; the Helipilot computers and the vertical gyros were destroyed by impact and fire, so a more detailed inspection of these components could not be performed.

In the maintenance records, it was found that the roll linear actuator of the SAS2 should have been replaced three days after the respective finding by maintenance, not counting the day of detection, and yet this component was not replaced as established in the MEL authorized by SAA, which was based on the MMEL revision "D".

Based on MMEL revision "E" of EASA, the replacement of the SAS2 roll linear actuator should have been performed, at the latest, on December 23rd, 2018, i.e., 10 days after the linear actuator failure was detected, although the maintenance area should have secured the SAS on the same day of the finding.

The MMEL, in its revision "E", states that the **AUTOTRIM** becomes inoperative with the failure of a SAS; the Flight Manual of the helicopter restricts its operation to visual flight rules and indicates, in addition, that the flight be performed up to a maximum speed of 128 KIAS and/or a rate of climb of 1,000 ft/min, above 500 ft above the ground; in all other conditions, the helicopter must be flown manually.

In the event that both SAS are inoperative, they must be deactivated and secured; when this happens, the pilot will not have the **FD (Flight Director)** modes available and will also not be able to engage SAS1, SAS2 and ATT HOLD.

On December 24th, 2018, the helicopter should not have operated due to SAS2 being affected by MEL.

Apart from this restriction on SAS operation, no other restrictions were found for helicopter operation.

2.2.4. Flight operations.

It is noted that, from the audio evidence of the communications established between the XA-BON and Puebla Control Tower, it is possible to determine that the XA-BON did not show any unusual frequency behavior during the communications established with the Air Traffic Services.

The crew performed the flight under visual flight rules, with good visual weather conditions, flying with hands off the controls, in autopilot configuration.

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The SAA Dispatch area released the helicopter without any restriction regarding the operation of the SAS2. Furthermore, according to the evidence obtained, the dispatch area was not aware of the intermittent failure, since the SAS2 deferral by MEL was not recorded in the flight and maintenance log; however, the crew was aware that SAS2 was out of service.

During the straight and level flight phase, after takeoff from the El Triangulo heliport (actually, from the backyard of a private residence), the electromechanical roll linear actuator of the SAS1 developed an internal failure caused by two loose screws inside the actuator that were moving freely on its electronics board, which resulted in the loss of the ability of the Helipilot to control the failed electromechanical linear actuator (i.e., uncommanded extension displacement) or disengagement of the integrated flight control system.

The "disconnection of the SAS1" means the activation of the linear actuator brake on the pitch, roll and yaw axes; also, in the disconnection of the SAS1, the "SAS1 OFF" caution message (MC) is displayed on the EDU (Electronic Display Unit) on the side of the pilot.

Based on the information available, it was not possible to determine the nature of the intermittent malfunction of the roll linear actuator of Stability Augmentation System number two (SAS2).

If an intermittent malfunction of the roll linear actuator of Stability Augmentation System number two (SAS2) resulted in uncontrolled extension of the linear actuator and if a loose screw inside the roll linear actuator of Stability Augmentation System number one (SAS1) made contact with terminals 1 and 2 of the electronics board within 3.5 seconds of reaction to the uncontrolled movement of the roll linear actuator of Stability Augmentation System number two (SAS2), that may result in a sudden uncontrolled roll to the left.

The crew did not adhere to the limitations established in the Flight Manual due to the intermittent malfunction of the SAS2 roll linear actuator. The Flight Manual limitations indicate to fly attentively at up to 128 knots of speed and to operate the controls manually when the flight speed exceeds 128 knots.

Based on the statements of witnesses who observed the helicopter "yaw", i.e., execute yaw axis movements, the manual corrections that were made on board can be correlated.

If the pilot was flying in hands-free mode without touching the controls and a SAS failure occurs, with a high-speed flight, he has a response time of 3.5 seconds, according to the helicopter certification; in this time, the pilot must recognize the failure and initiate corrective action (reaction time), before taking control of the helicopter manually. Therefore, to result in a catastrophic effect, the two actuators on the same axis would have to have moved, without being commanded by the crew, to "***hardover***", "***simultaneously***".

In the MMEL revision "D" and "E", the operational procedure indicates that the pilot will not have the Autotrim System available when a SAS is inoperative, in addition to restrictions in the operation of the helicopter such as: Flying under visual flight rules, traveling at a maximum speed of 128 knots, keeping a climb rate of 1,000 ft/min and flying above 500 ft above the ground. The

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crew must have been aware of the need to reduce speed to below 128 knots.

In the pre-flight checklist, the crew, according to the Flight Manual section 2, Standard Procedures, should have checked the cyclic stick control, the pedals, the SAS switches, that the pitch and roll bars of the helipilot were being followed and that there was no out-of-service SAS message.

2.2.5. Load and balance.
The load and center of gravity of the helicopter were within the prescribed limits, so it is not considered a contributing factor for the occurrence of the accident.

2.3. Survival.

2.3.1. Rescue and firefighting service response.
The accident site was located 2.4 miles from the VOR PBC; the PBC air terminal firefighting services were not involved because the site was not within their radius of action.

The Puebla Airport Command (Search and Rescue Coordination Center), indicated that the search and rescue activities were initiated by the Air Traffic Controller of the Puebla station, who issued the insertion phase when no response was received from the XA-BON at 14:39 hours (20:39 UTC), although residents of Santa Maria Coronango observed the accident and immediately reported it to the municipal police, who were the first responders cordoning off the site; the municipal police indicated in their report that the San Pedro Cholula Fire Department arrived at approximately 14:55 hours (20:55 UTC), managing to extinguish the fire in its entirety at approximately 15:25 hours (21:25 UTC).

The Search and Rescue Coordination Center did not receive the official notification about the reception of the ELT signal in the COSPAS-SARSAT system.

2.3.2. Analysis of fatalities and injuries.
The two pilots and three passengers were fatally injured as a result of the heavy impact with the terrain, which occurred at a very high speed and with the helicopter tilted forward, causing the cockpit and the roof to be compacted.

According to the report of the medical examiners, the cause of death of the pilots was a combination of trauma.

2.4 Organization.

2.4.1. Servicios Aereos del Altiplano, S. A. de C. V.
The operator had an Operational Safety Management Manual approved on December 19th, 2018, i.e., they were in phase 1 of the certification process, so their operational safety system was being implemented and, consequently, they did not have a certification and monitoring of it.

The operator had the obligation to inform its pilots, maintenance technicians and dispatch officers, the latest update of the MEL based on the MMEL revision "E" of the manufacturer, issued in May 2018, as well as to coordinate with the maintenance workshop the filling of the flight and maintenance log to record the deferred reports and that its area of

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dispatch would also be aware of this, in order to understand the content of the deferral, in accordance with current regulations.

Servicios Aereos del Altiplano had a MEL authorized by the Aeronautical Authority, dated March 08th, 2017, based on the MMEL Revision "D" dated December 10th, 2015.

The operations (except the crew) and dispatch areas of the operator (SAA), were not aware that the helicopter was operating with an intermittently failing SAS since December 13th, 2018. The flight and maintenance log containing the last flights were on board, without having rescued the original copies that corresponded to the maintenance and operations areas.

It should be noted that there is evidence that the Maintenance area of the organization received the notification, via email, of the generation of discrepancy number 21/2018, dated December 13th, 2018, by the RFS workshop; therefore, this area did have knowledge of the intermittent malfunction of the roll linear actuator of the SAS2.

The aircraft operator never obtained a subscription with LHD to have full access to the A109S helicopter technical and operational publications information; however, the manufacturer of the helicopter created a (highly restricted) user ID account for them on the LHD Customer portal to ensure that SAA had full-time access to the EASA Rotorcraft Flight Manual (RFM), Optional Equipment Supplements (OES), Service Bulletins (SB) and the Aircraft Maintenance Information Planning (AMPI), but it did not have a subscription to the full suite of A109S Technical and Operational Publications.

After the extraordinary major technical verification carried out by the DGAC, from January 29th to February 1st, 2019, the air operator submitted to the Aeronautical Authority evidence among which the training and education program, included in the General Operations Manual, Chapter IV, pages 1 to 9, stands out; however, no training policies are observed within the document. They presented evidence of CFIT and RVSM courses and documents related to initial or periodic training in Aviation Safety and Human Factors

The General Operations Manual revision 7, in the "*Minimum Equipment List and Missing Parts List*" section states:

> ***"The Director of Operations, Flight Crew and Operations Officer, and contracted Authorized Aeronautical Workshop personnel will coordinate everything necessary to ensure that aircrafts do not fly with Minimum Equipment List (MEL) reports."***

Regarding "Maintenance actions", they state:

> ***"The maintenance personnel of the contracted Authorized Aeronautical Workshop will correct as soon as possible the technical irregularities, in order to deliver the aircraft in fully operational conditions; when for reasons due to lack of time, lack of spare parts or lack of means, a failure cannot be corrected, maintenance will complement the deferred item in the technical flight report according to the established procedure, labeling in cabin the controls or indicators accessible by the crew specified in the MEL and applying, if so described in the MEL, the relevant maintenance procedure."***

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2.4.2 Rotor Flight Services, S. de R. L. de C. V.
The RFS workshop has an Operational Safety Management Manual, approved on October 23rd, 2018; it was in phase 1 of the certification process, so the safety system was being implemented, and because of that, they did not have an operational safety certification and monitoring.

In filling out the maintenance records, it was detected that some work orders and service release tags did not have complete information in the flight and maintenance log; work was performed that began with the opening of a discrepancy, however, a long time elapsed to close it.

Although there was a Quality Control Area within the RFS organization, on which Inspection depended, they were unable to put barriers in place to detect, on three occasions, that the MEL of SAA was not applied, for the intermittent failure of the SAS2 roll linear actuator.

The engineering area of the workshop sent to the maintenance area of the operator the discrepancy form number 21/2018, dated December 13th, 2018, via email.

2.4.3. Federal Civil Aviation Agency (AFAC, formerly DGAC)
On December 19th, 2018, the Aeronautical Authority granted the renewal of the Air Services Operator Certificate to the operator; in this renewal, they did not verify that the MEL of the Air Services operator was outdated, considering that in May 2018 the EASA had published version "E" of the MMEL.

The Civil Aviation Authority did not identify the lack of a Minimum Equipment List (MEL) revision policy, when there was an update to the Master Minimum Equipment List (MMEL) at Servicios Aereos del Altiplano, S. A. de C. V. (SAA), during the last renewal of the Air Operator Certificate (AOC), on December 19th, 2018; likewise, it has also not established a policy that considers an acceptable timeframe for Operators to implement the necessary amendments to their MEL's, to be authorized again, once they comply with the applicable update.

The last ordinary technical-administrative verification performed to SAA by the Civil Aeronautical Authority (CAA), on August 18th, 2016, exceeded the required annual technical-administrative verification terms.

During the extraordinary technical-administrative verification conducted in January 2019 to the Servicios Aereos del Altiplano, S. A. de C. V. (SAA) operator, the aeronautical verifying inspectors of the Civil Aviation Authority did not identify that SAA did not have a policy to implement amendments to the Minimum Equipment List (MEL) when a new version of the MMEL is published.

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3. CONCLUSIONS.

1. The crew was duly certified and qualified to operate the helicopter, in accordance with Mexican regulations.
2. The medical and psychological condition of the crew was not a factor in the occurrence of this accident.
3. Due to the high impact forces against the terrain, it was not possible that there were any survivors of the accident.
4. The aircraft had airworthiness certificate number 20181252, issued on September 21st, 2018, effective on September 19th, 2020.
5. On December 13th, 2018, the maintenance technicians of the Rotor Flight Services, S. A. de C. V. (RFS) aeronautical workshop generated discrepancy form number 21/2018, indicating in the interview that it was issued based on a verbal report from the XA-BON crew of "sudden course change". The aeronautical workshop maintenance personnel performed the fault isolation, finding the roll linear actuator serial number (S/N) see 3 -118 of Stability Augmentation System number two (SAS2) to be damaged, proceeding to inform the operator (SAA).
6. The maintenance technicians of the Rotor Flight Services, S. A. de C. V. aeronautical workshop found the failure in the roll linear actuator of Stability Augmentation System number two (SAS2); however, according to the statement of the personnel itself, they did not record in the flight and maintenance log that the roll linear actuator of Stability Augmentation System number two (SAS2) was deferred, according to the Minimum Equipment List (MEL) of the Operator.
7. Although within the organization of the Rotor Flight Services, S. A. de C. V. aeronautical workshop there is a quality control area on which the Inspection Area depends, on three occasions they did not adhere to the Minimum Equipment List (MEL) of the helicopter operator, Servicios Aereos del Altiplano, S. A. de C. V. (SAA), in order to defer the roll linear actuator of Stability Augmentation System number two (SAS2).
8. The Minimum Equipment List (MEL) of the operator required the replacement of Stability Augmentation System number 2 (SAS2) roll linear actuator within 3 days. The replacement of this linear actuator should have been completed no later than December 16th, 2018.
9. If the dispatch area of the operator, Servicios Aereos del Altiplano, S. A. de C. V., had been aware of the intermittent malfunction of the roll linear actuator of Stability Augmentation System number two (SAS2), they would have had to ground the helicopter.
10. The Minimum Equipment List (MEL) of the operator, Servicios Aereos del Altiplano, S. A. de C. V. (SAA), based on the MMEL revision "D", was authorized by the Aeronautical Authority, although it did not have the applicable update according to the current Master Minimum Equipment List (MMEL) under revision "E", published in May 2018 by the European Civil Aviation Agency (EASA); it is worth mentioning that the operator (SAA) did not have a policy in its Manuals approved by the Aeronautical Authority, to update its Minimum Equipment List (MEL) within a technically reasonable period when a new version of the Master Minimum Equipment List (MMEL) was published.
11. The helicopter was not airworthy, as of December 17th, 2018, due to exceeding the required timeframe for the replacement of Stability Augmentation System number two (SAS2) roll linear actuator.
12. The crew decided to continue operating the helicopter, being aware of an intermittent failure of the roll linear actuator of Stability Augmentation System number two (SAS2), which was not replaced within the interval required by the Minimum Equipment List (MEL).

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13. The load and center of gravity of the helicopter were within the limits established by the manufacturer on its flight guidelines.
14. Weather conditions are not considered a factor in the occurrence of the accident.
15. According to witness statements, no components were detached from the helicopter during the flight. Witnesses saw the helicopter turn to the left until it inverted and descended to the ground.
16. The inspection of the remains of the basic body, engines, rotor system and flight control system that were analyzed, with the exception of those that were destroyed by fire, revealed no evidence of malfunction or failure that would have prevented the normal operation of the helicopter [excluding the roll linear actuators of Stability Augmentation Systems number one (SAS1) and number two (SAS2)].
17. In the roll linear actuator of Stability Augmentation System number one (SAS1), two screws located at one end of the linear actuator body were detached internally, which held the electronics board to the linear actuator; it was determined after testing that: ***"if a screw makes contact with terminals 1 and 2 of the electronics board, it allows the possibility of an uncommanded displacement in the extension direction of the linear actuator".***
18. Based on the information available, it was not possible to determine the nature of the intermittent malfunction of the roll linear actuator of Stability Augmentation System number two (SAS2).
19. If a malfunction of the roll linear actuator of Stability Augmentation System number two (SAS2) resulted in uncontrolled extension of the linear actuator and if a loose screw inside the roll linear actuator of Stability Augmentation System number one (SAS1) made contact upon movement with terminals 1 and 2 of the electronics board within 3.5 seconds of reaction to the uncontrolled movement of the roll linear actuator of Stability Augmentation System number two (SAS2), this may result in a sudden, uncontrolled leftward roll.
20. If the pilot flying was operating the helicopter manually (hands on the flight controls), he should have compensated for the sudden and uncommanded roll movement that led to the simultaneous extension of both linear actuators.
21. The crew did not adhere to the limitations set forth in the Flight Manual that were in effect due to the intermittent malfunction of the roll linear actuator of Stability Augmentation System number two (SAS2). The Flight Manual limitations indicate to fly attentively at up to 128 knots of speed and to operate the controls manually when the flight speed exceeds 128 knots.
22. Due to the lack of data from a crash-protected flight recorder, several factors in the accident could not be thoroughly investigated. These factors include: 1) the performance of the crew during the flight, 2) the true speed at which the helicopter was traveling, 3) any early warning, by lights or audible cockpit alarm that the crew may have had due to failure of a linear actuator, 4) the leftward roll rate of the helicopter, and 5) the reaction and response of the pilot to the sudden, uncommanded, leftward roll.
23. The last technical-administrative verification to SAA was performed by the Civil Aeronautical Authority (DGAC) on August 18th, 2016, exceeding the required annual technical-administrative verification terms.
24. The Civil Aviation Authority has not established a policy for reviewing and updating the Minimum Equipment List (MEL) to the Operator.

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PROBABLE CAUSE

The Aviation Accidents and Incidents Investigation and Judgment Commission, based on articles 1, 2, section I, 14, 16, 18, 26, and 36 section XXVII of the Organic Law of the Federal Public Administration; 2 section XVI, sub-section XVI.5, 9, and 21 section XXIII of the Internal Regulations of the SCT; 189 and 190 of the Regulations of the Civil Aviation Law and 7.9 Organization Manual of the General Directorate of Civil Aeronautics, and the Mandatory Circular Document CO AV-83.1/07, determined as the probable cause of this event:

"Loss of control of the helicopter due to a sudden roll to the left, which was not recovered by the pilot in command, causing the helicopter to invert its position during flight and impact with that configuration against the terrain."

"Although the information available for the investigation was limited due to the lack of impact-protected flight recorders and the severe damage to the helicopter from the ground impact and subsequent fire, based on the available evidence, it could be determined that the sudden roll to the left was possibly due to both roll linear actuators extending simultaneously, without being commanded."

PHASE

Ascent

CONTRIBUTING FACTORS.

1. Inefficient maintenance practices by the company providing the maintenance service.
2. Inadequate operational safety culture of the operator.
3. Pressure from the operator to continue flights with knowledge of an intermittent malfunction of the roll linear actuator of the Stability Augmentation System number two (SAS 2), beyond the respective requirements outlined in the Minimum Equipment List (MEL) applicable to the helicopter.
4. Insufficient supervision of the maintenance and operation of the helicopter by the Civil Aviation Authority.

RECOMMENDATIONS

Federal Civil Aviation Agency (AFAC)

For optimal operational safety surveillance and, if applicable, for the investigation of aviation accidents and incidents, it is essential to have non-volatile memory components installed in an aircraft, which store information after an accident, provide operational safety information, and allow directing, clarifying, and accelerating the investigation process; additionally, having the support of a voice recorder and a flight data recorder allows the investigators to evaluate more factors of the aircraft operation. In the process of this investigation, it was detected that the XA-BON helicopter belonged to a company that provides public passenger service, and the helicopter was not required to have a flight data recorder and voice recorder. Due to the above explanation, the Commission issues the following recommendation:

Rec. 001/2020 Regulate that all rotary-wing aircraft intended for public passenger service have a voice recorder and/or a flight data recorder installed;

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and carry out checks to ensure that these components are recording information correctly.

The XA-BON helicopter stated in its flight plan that it would land on an authorized heliport; however, the investigations and interviews with witnesses showed that this helicopter landed and took off from the backyard of a house, which increases the danger in air operations due to the lack of compliance with the regulations in force regarding operational safety and security of the facilities. The Commission determined that these facts were not a factor for the occurrence of the accident, but observed that there is an area of opportunity to guarantee the safety of helicopter operations destined for public passenger service. For that reason, the Commission issues the following recommendation for you:

Rec. 002/2020 Conduct a comprehensive diagnosis on the operation of current heliports and regularize the existing ones in order to create the figure of public heliports that can receive operations from third parties and raise safety standards in helicopter operations for public passenger service.

The investigation determined that the operator, Servicios Aereos del Altiplano, S. A. de C. V. (SAA), had inadequate safety culture, given that it did not properly address the obvious hazards and operated the helicopter with a known intermittent malfunction of a linear actuator, beyond the requirements set forth by the Minimum Equipment List (MEL) of the helicopter. Therefore, the Commission issues the following recommendation for you:

Rec. 003/2020 Develop periodic workshops on helicopter maintenance for Aircraft Operators and Aeronautical Workshops to share best practices, lessons learned from accident investigations, and encourage the development and implementation of an effective Safety Management System (SMS).

Regarding pilot training, in the investigation, it was detected that the crew had an annual emergency course as established by Mexican regulations; however, according to point 7.4.3.1. of Annex VI, Part III, International Operations - Helicopters, of the ICAO, it was established that the competence of pilots must be demonstrated and that these verifications must be carried out twice a year; therefore, the Commission recommends you to:

Rec. 004/2020 Require operators holding an Air Service Operator Certificate to certify the technique and ability of pilots to execute emergency procedures, as well as to verify the competence of pilots. These verifications should be performed twice a year.

A very important aspect that could have mitigated the occurrence of this accident is if the pilots had recorded in the maintenance log any anomaly detected during the operation of the helicopter, which would have allowed all those involved in the operation to know the operational restrictions and dispatch the aircraft safely; derived from that, the Commission recommends you to:

Rec. 005/2020 Require operators holding an Air Service Operator Certificate to disseminate within their organizations that any anomaly detected in flight by pilots shall be recorded in the flight log so that the crew, maintenance, operations, and dispatch areas can follow up on it and, if applicable, defer it according to the authorized Minimum Equipment List (MEL); and ensure that when the component affected

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[Logo 2020LEONA VICARIO]

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by this list requires replacement, the operator, crew, and/or workshop perform the appropriate procedures within the times established in this document.

The investigation found that the operator lacked, in its authorized manuals, a policy for updating the Minimum Equipment List (MEL). The Commission is concerned that other operators do not have a policy approved by the Aviation Authority to update their authorized Minimum Equipment List (MEL) within a technically reasonable period following a revision to the Master Minimum Equipment List (MMEL). Therefore, the Commission recommends to:

Rec. 006/2020 Conduct a review of all operators holding an Air Service Operator Certificate to ensure that they have a policy to update their Minimum Equipment Lists (MEL) within an approved timeframe and promptly and effectively address any updates to the Master Minimum Equipment List (MMEL).

Section D81 Minimum Equipment List Authorization of the AOC, subsection (b), MEL Management Program, states that the Air Service Operator Certificate holder shall develop and maintain an adequate program for the management of repairs to the components and/or accessories listed on the approved MEL and shall include in a document or its manual a description of the MEL management program. In this MEL management program, the Operator shall include at least the following. 1. A method that provides for tracking the date, and when appropriate, the time the component and/or accessory was deferred and subsequently repaired. The method should include a review of the number of each component and/or accessory deferred to determine the reason for any delay in repair, length of the delay, and the estimated date by which the component and/or accessory will be repaired. 2. A plan to concentrate parts, maintenance personnel, and aircraft to a specific time and place for repair. 3. A review of components and/or accessories deferred due to parts unavailability to ensure that a purchase order with a firm delivery date is in place. 4. A description of the specific duties and responsibilities per position, according to the organizational chart of the certificate holder, of the personnel in charge of the management of the MEL management program; also, in the Regulatory Appendix section, point 5.8. of the Mexican Official Standard NOM-018-SCT3-2012 "That establishes the content of the Flight Manual," establishes that Permit holders and concessionaires of the public air transport service must maintain updated the information contained in the MEL, when: ... A new revision to the MMEL is published; according to this evidence the MEL requirements are disseminated in these documents, which causes it not to be easy for the operators to comply with all the requirements that the Authority has established for the MEL; for such reason, the Commission considered issuing the following recommendation for you:

Rec. 007/2020 The regulations should be updated, ensuring that this document contains all the policies to be complied with by the Operators in relation to the Minimum Equipment List (MEL).

The regulations require the Civil Aviation Authority to conduct an annual technical-administrative verification of all operators that hold an Air Service Operator Certificate. The investigation identified that 20 months have passed since the Civil Aviation Authority performed the last technical-administrative verification to the Servicios Aereos del Altiplano, S. A. de C. V. (SAA) operator. The Committee is concerned that the technical-administrative verifications, routine or otherwise, are not carried out in a timely manner and may result in safety issues that remain unidentified and unaddressed. Therefore, the Committee recommends you to:

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Rec. 008/2020 Conduct a review of all aircraft operators holding an Air Service Operator Certificate (AOC) to ensure that they have complied with their annual technical-administrative verification.

It was learned through various sources that the Second Section of the General Staff of the Secretariat of the Navy reported that the ELT radio beacon of the XA-BON helicopter had been activated 9 minutes after take-off, at 14:43 hours; however, according to the Search and Rescue Coordination Sub-Center (Puebla Airport Command) they indicated that they did not receive any official notification from the Cospas-Sarsat Mission Control Center; therefore, the Commission pointed out that in order to be able to attend to the victims of an air disaster and save lives, it is indispensable that the notification coordination is made in time and form to activate the rescue groups. Due to the foregoing, it recommends you to:

Rec. 009/2020 Strengthen search and rescue communications between the Cospas-Sarsat Mission Control Center (Secretariat of the Navy, SAR-Mexico) and the Search and Rescue Coordination Centers (Regional Commands) so that upon receiving a signal from the ELT, the Emergency Operational Center (search and rescue sub-center) can organize the search and rescue brigades and can immediately go out to attend to and provide these services to the victims of an air crash, following the Emergency Plan of each Air Terminal in the country.

Servicios Aereos del Altiplano, S. A. de C. V.

In the investigation of the accident of the XA-BON helicopter, the investigators and experts who participated detected that the Minimum Equipment List (MEL) of the XA-BON, which was used by the aeronautical technical personnel, was updated based on revision "D" of the Master Minimum Equipment List (MMEL) issued in 2015; revision "E" of the Master Minimum Equipment List (MMEL), issued in May 2018, contained important modifications regarding how to deal with failures in the Stability Augmentation System (SAS), now involving maintenance areas; in this case, the technicians did not have the updated information; for this reason, the Commission recommends you to:

Rec. 010/2020 Implement procedures and courses to ensure that the aeronautical technical personnel of your organization use only current and authorized technical information, ensuring that the operation of the aircraft registered on your Air Service Operator Certificate (AOC) is safe.

In the investigation process, it was detected that the organization did not have a subscription to the Technical Publications package for the A109S helicopter. If this is not corrected, it may cause that the aeronautical technical personnel involved in the operation of the aircraft are not working with the most updated technical information; as SAA operates other aircraft models, the Commission considers that this same situation may be occurring with the other aircraft models that are under the management of SAA. Therefore, the Commission considers that a review of the technical information applicable to the fleet of SAS is necessary and recommended to rectify possible outdated publications; therefore, the commission urges you to:

Rec. 011/2020 Conduct a review process to the technical publication subscriptions that apply to the aircraft of the Organization to ensure that Servicios Aereos del Altiplano is using the complete package of subscriptions and all updated information issued by the manufacturers.

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Rotor Flight Services, S. de R. L. de C. V.

In some maintenance records generated by this aeronautical workshop, derived from inspections and scheduled services, discrepancies, and work orders related to the XA-BON aircraft, to which the investigators had access, it was found, among other findings, that: In work order RFS-0239/2016, they did not include the result of the inspections performed by an external workshop; the service release tag, dated January 5th, 2017, refers to work order RFS-002/2017; however, they did not specify the technical data of the repaired engine and did not include all the information of the components; discrepancies 21/2018 and 30/2018 begin with the opening, however, much time elapsed for them to be closed; there is no evidence in the maintenance log that they deferred by MEL chapter 22 Autopilot, Stabilization Augmentation System (SAS), since more than three days passed for the installation of the linear actuator. Derived from the above, the Commission recommends you to:

Rec. 012/2020 Implement a procedure to ensure that the aeronautical technical personnel of that workshop perform the correct and complete filling of work orders, discrepancy forms, describe in detail such work and if an inspection performed involves a deferral per the Minimum Equipment List (MEL), such deferral is carried out, as applicable according to the respective report in the flight log by the crew or the quality control inspector and recorded in the maintenance log.

Rec. 013/2020 Spread among maintenance technicians that any verbal report of malfunction or failure of any system received from crews or other technical personnel involved in the operation of the aircraft is followed up and recorded in the flight and maintenance log for proper traceability.

Security actions
Honeywell
The linear actuator manufacturer recognizes that the fastener assembly associated with the linear actuator electronics board, spacer, and security washer, along with the specified length of the fastener screws on the linear actuator electronics board, resulted in only 2 to 3 coupling threads of the fastener screws being threaded into the body of the linear actuator; for such reason, it will investigate changes in, but not limited to, 1) the screw length to ensure better coupling of the fastener screws into the linear actuator holes; as well as, 2) assembly procedures to reduce the risk of damage to the hole threads during screw installation. Additionally, the condition in which an unintentional short circuit between terminals 1 and 2 of the electronics board can lead to the full extension of a linear actuator, so 3) it will investigate possible solutions to avoid short circuits between terminals 1 and 2 of the electronics board inside the linear actuator. An update on the progress of these actions will be provided to the investigating team in July 2020.

Sincerely
The Chairman of the Commission

[Illegible signature]
Jose Armando Constantino Tercero
Professional License 1718542

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[Illegible Signature] [Illegible Signature] [Illegible Signature] [Illegible Signature] [Illegible Signature]

References to the public version of the Final Accident Report of the aircraft with registration number XA-BON, file number ACCDTARA004/2018MMPB

1.
Deleted: Geographical coordinates of take-off.
Legal basis: Article 113, section I of the Federal Law for Transparency and Access to Public Information (LFTAIP), in connection with paragraph Thirty-eight, section I of the General Guidelines for the classification and declassification of information, as well as for the preparation of public versions.
Reasons: Confidential data, since they are geographic coordinates that allow the full identification of a private residence, which violates the private sphere of the inhabitants of the same.

2.
Deleted: Personal data (name, sex, age, nationality, among others) of aeronautical technical personnel.
Legal basis: Article 113, section I of the Federal Law for Transparency and Access to Public Information (LFTAIP), in connection with paragraph Thirty-eight, section I of the General Guidelines for the classification and declassification of information, as well as for the preparation of public versions.
Reasons: Confidential information, since it refers to personal data of individuals; therefore, the consent of the individual is required for its distribution and publication.

3.
Removed: Technical data such as serial numbers related to various aircraft components.
Legal basis: Article 113, section II of the Federal Law for Transparency and Access to Public Information (LFTAIP), in connection with paragraph Thirty-eight, section III of the General Guidelines for the classification and declassification of information, as well as for the preparation of public versions.
Reason: Confidential information, since it refers to commercial data of the components since the serial numbers are unique in their class and allow full identification of the component.

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[Logo: 2020LEONA VICARIO].

[Illegible Signature] [Illegible Signature] [Illegible Signature] [Illegible Signature] [Illegible Signature]

Attachment A

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[Logo: 2020LEONA VICARIO]
2020
LEONA VICARIO

Content

1. Correspondence between RFH and PHP-PAL
2. Flight and maintenance log folio 0785.
3. Discrepancy 09/2018.
4. Findings in maintenance records.
5. Schematic diagram of the AFCS.
6. Automatic stabilization system.
7. Auto-trim system.
8. FD System.
9. FD control panel.
10. Flight and maintenance log folio 421.
11. Flight and maintenance log folio 434.
12. Discrepancy 028/2017.
13. Discrepancy 030/2017.
14. ELT activation reports.

DEC 19, 2018

Note 1

From: Rotor Flight Services <[redacted]>
Sent: Wednesday, December 19, 2018 12:11 PM
To: Note 1
Subject: RE: ACTUATOR LINER QUOTE

Follow Up Flag: FollowUp
Flag Status: Flagged

Good morning, Note 1

B

The client tells me that if it is removed, the machine will be out of service and the work schedule is a little busy right now, so it is not possible to stop or leave it out of service these days. We are also trying to find a way to prevent the machine from being out of service, I will let you know what we got.

Greetings,

LCE, Note 1
Material Resources
Note 1
Phone: [redacted]
Cellphone: [redacted]

From: Rotor Flight Services < Note 1 >
Sent: Tuesday, December 18, 2018 10:35 am
To: Note 1
Subject: RE: ACTUATOR LINER QUOTE

OK let me request it with my client and I'll let you know

Thank you

LCE, Note 1
Material Resources
Note 1
Phone: [redacted]
Cellphone: [redacted]

From: Note 1
Sent: Tuesday, December 18, 2018 08:33 am
To: Rotor Flight Services
Subject: RE: ACTUATOR LINER QUOTE

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Hello, Note 1

A

Do you have time to send it for Warrant AOG repair? In 2-3 days after it has been received by the workshop, it can be evaluated and then repaired.

[Illegible Signature] [Illegible Signature] [Illegible Signature]
[Illegible Signature] [Illegible Signature]

[Logo: SAASA] SERVICIOS AEREOS DEL ALTIPLANO, S.A. DE C.V. Log Book **Nº 0785**

AIRCRAFT: AGUSTA, A1095	PILOT: Note 1	LIC: Note 1	ADVISER:	LIC:
MANIFACURING YEAR: 2010	COPILOT: Note 1	LIC: Note 1	FLIGHT CLASS:	
SERIES NO: 22174				
ID: XA-BON	COMMANDER'S SIGNATURE: Note 1		CONTRACT No:	

ROUTE:	UTC HOUR TAKE OFF/LANDING	 WEDGE/WEDGE	FUEL	DATE: JUN 25-18
FROM: HUM	03:20	03:18	240	PASSENGERS
TO: HAQ	03:52	03:59	110	4
PARTIAL	FLIGHT TIME: 00:32	WEDGE TIME: 00:36	130	
FROM: HAQ	03:56	03:54	110	PASSENGERS
TO: HPW	04:00	04:02	100	-
PARTIAL	FLIGHT TIME: 00:04	WEDGE TIME: 00:08	10	
FROM:				PASSENGERS
TO:				
PARTIAL	FLIGHT TIME:	WEDGE TIME:		
FROM:				PASSENGERS
TO:				
PARTIAL	FLIGHT TIME:	WEDGE TIME:		
TOTAL	00:36	00:44	140	4

TIME CONTROL				
FROM:	PRIOR LOGBOOK	THIS LOGBOOK	REAL TIME	LAST MAJOR REPAIRMENT
BASIC BODY:	T.T.: 1964:04 T.U.R.M.: N/A	00:36	1965:40	
ENGINE Nº 1: PRATT & WHITNEY PW207C NS: PCE-BH-0434	T.T.: 1964:04 T.U.R.M.: N/A	00:36	1965:40	
ENGINE Nº 2: PRATT & WHITNEY PW207C NS: PCE-BH-0499	T.T.: 1721:47 T.U.R.M.: N/A	00:36	1722:23	
1ST CYCLE	8717	2	8719	
2ND CYCLE	1690	2	1692	
LANDING	7734	2	7736	

ENGINE READINGS		N 1	ITT	N 2	FLOW	OIL PRESS	OIL TEMP	BATTERY TEMP	MTOW	FLIGHT HEIGHT LEVEL	O.A.T.	MACH IAS	RVSM ALTIMETER
1ST SECTION	ENGINE Nº 1												LH RH STBY
	ENGINE Nº 2												
2ND SECTION	ENGINE Nº 1												LH RH STBY
	ENGINE Nº 2												
3RD SECTION	ENGINE Nº 1												LH RH STBY
	ENGINE Nº 2												
4TH SECTION	ENGINE Nº 1												LH RH STBY
	ENGINE Nº 2												

MAINTENANCE
[Illegible Signatures]

[Illegible Signature]
[Illegible Signature]

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SERVICIOS AEREOS DEL ALTIPLANO, S.A. DE C.V. [Illegible Signature]

ID:	AIRCRAFT	MAINTENANCE REPORTS	LOGBOOK		Nº 0785
XA-BON	AGUSTA A109S				
No.	OBSERVATIONS/REPORTS	REPORT CORRECTIONS	DATE	BASE	MECHANIC, SIGNATURE AND LICENSE NO.
	SUDDEN CHANGE IN DIRECTION WITH FLIGHT DIRECTOR ENGAGED	Inspection of the flight director's system was carried out and discrepancy 09/2018 was generated, requesting the electric Actuator. Note 1	06/25/18	Pbc	
NAME, SIGNATURE PILOT AND LICENSE NO	Note 1 DATE: JUN/25/18				

DEFERRED UNDER M.E.L.

No.	OBSERVATIONS/REPORTS	RELEASE CATEGORIES UNDER M.E.L.	DATE	BASE	MECHANIC, SIGNATURE AND LICENSE NO.

APPLIED AD'S AND SB'S CONTROL

DIRECTIVES / BULLETINS TO GLIDER	DIRECTIVES TO ENGINES		BULLETINS TO ENGINE	
	POS 1	POS 2	POS 1	POS 2

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IRREGULARITIES REPORT

No	IRREGULARITIES REPORT	IRREGULARITIES CORRECTION	DATE	BASE	MECHANIC'S SIGNATURE AND LIC. Nº

ENGINE OIL CHANGE

	1[ST] SECTION	2[ND] SECTION	3[RD] SECTION	4[TH] SECTION
ENGINE Nº 1				
ENGINE Nº2				

UNIT CHANGE REPORT

UNIT NAME	PART No.	POS.	SERIAL NO. REMOVED	SERIAL NO. INSTALLED	REASON TO CHANGE	DATE	BASE	MECHANIC SIGNATURE AND LICENSE NO.	I CERTIFY TO HAVE CARRIED OUT THE PRELFIGHT AND POSTFLIGHT INSPECTION, AS WELL AS THE DAILY INSPECTION ACCORDING TO MANUFACTURER'S MANUAL, FINDING IT [ILLEGIBLE] Note 1 NAME, SIGNATURE AND LICENSE NO. OF RESPONSIBLE MECHANIC
REPORT REFERRAL	PV- PRELFIGHT. DS- TAKE OFF. AP- APRIMXATELY AR- START AC ASCEND. PA- STOP CA- [ILLEGIBLE]. CR: CRUISE. O-OTHER			REASON FOR CHANGE	1. LIFE [ILLEGIBLE]. 4. SCHEDULE. 7. CONVENIENCE 2. WEARING. 5. [ILLEGIBLE]. 8. FAILURE 3. INSPECTION 6. EVENT. 9. OTHER				Note 1 DATE: 06/25/18

[Illegible Signature] [Illegible Signature]

[Logo: Rotor Flight Services]

					DISCREPANCY No. 09/2018
AIRCRAFT DATA					
MODEL	A109S	SERIES	Note 2	ID	XA-BON
DATE	JUNE 26, 2018	CREATED BY:	Note 1	TIME OF OCCURRENCE	1964:40 HRS
DISCREPANCY DESCRIPTION					
BY FLIGHT REPORT. THE AIRCRAFT OCCASIONALLY DEVERSES HEADING TO THE RIGHT, WITH THE FLIGHT DIRECTOR ENGAGED. OPERATIONAL TESTS WERE PERFORMED IN ACCORDANCE WITH MM REF OB-A-22-11-00-00A-340A-A, A LINEAR ROLL SHAFT ACTUATOR WAS DAMAGED. IT REQUIRES REPLACEMENT.					
OBSERVATIONS			AUTHORIZED BY		
			Note 1		

CONSUMABLES AND PARTS

Nº	PIECE Nº / SERIAL Nº	DESCRIPTION	REQUIRED QUANTITY	PURCHASE ORDER Nº	WAREHOUSE VAUCHER Nº
1	Note 2	ACTUATOR, ELECTROMECHANICAL, LINER	01		
2					
3					
4					
5					
6					
7					
8					
9					[Illegible Signature]

CORRECTIVE ACTION			
The defective linear actuator was replaced according to MM REF OB-A-22-11-04-00A-520-A-A and OB-A-2211-04-00A-720-A-A, which was left working correctly. [Illegible Signature]			
ESTIMATED TIME:	2 HOURS	REAL TIME:	2 HOURS[Illegible Signature]
CARRIED OUT BY:	[Illegible Signature] Note 1	CONCLUSION DATE	JULY 4TH, 2018
INSPECTED BY:	[Illegible Signature] Note 1	CONCLUSION TIME	1978:36

[Illegible Signature]

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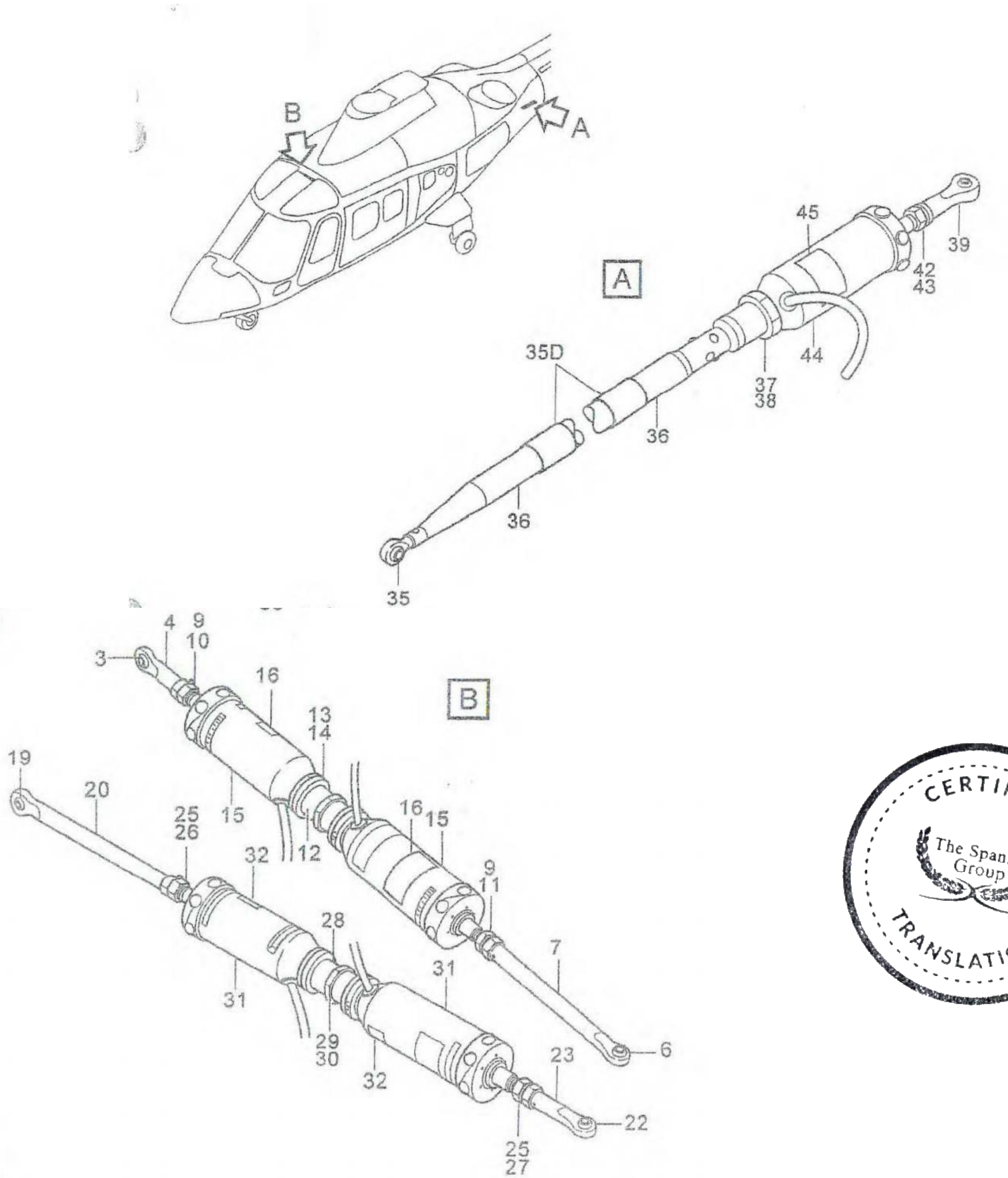
Calle 3 Modulo I
Toluca International Airport
Toluca, Mexico, ZC 50200
Phone: +52 722 2770541

RFS-DIS-REV 2
[Illegible Signature]



[Illegible Signature]
[Illegible Signature]
[Illegible Signature]

ICN-0B-A-221100-G-00001-00310-A-04-1

[Illegible Signature]

FIGURE 1. ACTUATOR INSL, CYCLIC AND TAIL ROTOR PITCH CONTROL

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NUMBER 2 VERTICAL GYROSCOPE SYSTEM Illustrated Parts Data – IPD

FIG ITEM	PART NUMBER....... NSN........	DESCRIPTION 1 2 3 4 5 6 7 8 9	**UOCA.. MVEFFECT..	I C Y	QNHA UI	SMR..
02	**Note 1**	**Note 1**				
-0			G		REF	XC
-1			**A G		REF	XC
-1			**B G		REF	XC
2			G		0001 EA	PAOLD
3			**A---- G		0004 EA	PAOZZ
3			**B---- G		0002 EA	PAOZZ
3A			**B---- G		0002 EA	PAOZZ
3B			**B---- G	-1	0004 EA	PAOZZ
3B			**B---- G	2-	0004 EA	PAOZZ
4			G		0004 EA	PAOZZ
5			G		0001 EA	PAOZZ
6			G		0001 EA	PAOZZ
-7			G		REF	XC
8			G		REF	XB
9			G		0001 EA	PAOZZ
10			G		0001 EA	PAOZZ
11			G		0001 EA	PAOZZ
12			G		0001 EA	PAOZZ
13			**B---- G		REF EA	PAOZZ
14			**B---- G	-3	REF EA	PAOZZ
14			**B---- G	5-	REF EA	PAOZZ

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[Illegible Signature] [Illegible Signature]

Work orders findings, records, stickers, component installation, etc. XA-BON N/S 22174 HELICOPTER

Item	W. O. Technical Date	Total A/C Time	Folio	Discrepancy	Component	Frequency	Described damage		Observations
						a) Time b) Calendar time	a) TLV b) Out of Limits c) Others	a) Requirements b) Causes c) Lacks external workshop information	
1	RFS-244 DEC 2, 16 Note 1	1,361.50	70	Engine #2 replacement due to impeller damage found	Removed engine PCE- Note 2 Note 2 Installed	a) 1,361.5 TT	c) damage to Impeller	It was sent to the manufacturer for repair, type of damage was not specified.	They do not have the times of both engines in the W.O., they do NOT have the certification of the engine change.
2	RFS-002/2017 JAN 05, 17 Note 1	1,349.90	100	56/2016	Engine without N/S	a) 1,349.9 TT	c) blade damage	Repair was carried out by the manufacturer P&W	They do not refer to this work, the sticker does not specify which engine is repaired. There are no dates and times in the W.O. 244/2016 and the W.O. RFS 002/2017.
3	RFS-238/2017 MAR 01, 16 Note 1	1,449.30	160	Power section: 200 hr inspection. Rec. every 50 hours at the request of the Client	No N/S engines are indicated	Every 50 hours	At the request of the client	a) customer requirement	They do not indicate if it is carried out to both engines.
4	RFS-239/2016 APR 08, 17 Note 1	1,449.21	214	Power section: 200 hr inspection. Rec. every 50 hours at the request of the Client. 100 hour baroscopic inspection Motor #1.	N/S Note 2	Every 50 and 100 hours	At the request of the client	a) customer requirement	Baroscopic inspection by External Workshop, it is not cited by the W.O. they also do not include the inspection's result. Discrepancy is opened in 2016 and it is closed or reviewed in 2017..
5	Without WO STICKER APR 12, 17	1,506.26	220	Discrepancy 048/2016 DAU N/P 109-0900-76-6401 was replaced, as there is no amperage indication in EDU No. 2, Channel A.	Note 2 Note 2		Because there is no amperage indication in EDU No. 2, Channel A.	Due to EDU failure	Repaired EDU is installed, they do not indicate time of each component

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Blvd Adolfo Lopez Mateos 1990, Col. Los Alpes, Alvaro Obregon. ZC 01010, Mexico City. Phone: 01 (55) 5723 9300

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Work orders findings, records, stickers, component installation, etc. XA-BON N/S 22174 HELICOPTER

Item	W. O. Technical Date	Total A/C Time	Folio	Discrepancy	Component	Frequency	Described damage		Observations
						a) Time b) Calendar time	a) TLV b) Out of Limits c) Others	a) Requirements b) Causes c) Lacks external workshop information	
6	Without W.O MAR 20, 17	1,476.47	187	08/2017 and 03/2016 and Compliance with Directives					Discrepancy 08/2017 (March 16, 2017 at 1,471.3 hours. Closed on March 20, 2017 at 1,476:47 hours)
7	Without W.O MAR 14, 17 Note 1	1,476.80	NT	Discrepancy 07/2017, indicates in the daily inspection, the clogged filter indicator of the hydraulic system No. 2 was detected. Requires inspection and cleaning.					It is detected in daily inspection at 1,466.4 hours, concluded on Mar 20, 2017 at 1,476.8 hours. It is corrected 10 hours later.
8	WO RFS-082/2017 JUN 22, 2017	1,600	325	1600 hours service: Baroscopic inspection performed on engine # 1 NS Note 2		a) 100 hours	Not reported on W.O	External workshop	No result of baroscopic inspection found on this W.O.
10	WO RFS-153/2017 JUL 03, 2017	1,603.47	330	Engine replacement # 2 Note 2 TT 243:37/TSO NEW. Is installed Note 2 BH0499, TSO NEW/CT 0/PT4222 / Impeller 0.	Note 2		Damaged impeller repaired by the manufacturer P&W	P&W	In the W.O, the times of both engines (the one removed and the one installed) are not settled, there is no certification for engine change by Command.

[Illegible Signature] [Illegible Signature] [Illegible Signature]

Blvd Adolfo Lopez Mateos 1990, Col. Los Alpes, Alvaro Obregon. ZC 01010, Mexico City. Phone: 01 (55) 5723 9300

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[Illegible Signature]

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Work orders findings, records, stickers, component installation, etc. XA-BON N/S 22174 HELICOPTER

Item	W. O. Technical Date	Total A/C Time	Folio	Discrepancy	Component	Frequency	Described damage		Observations
						a) Time b) Calendar time	a) TLV b) Out of Limits c) Others	a) Requirements b) Causes c) Lacks external workshop information	
11	Without W.O MAR 23, 2017 Note 1	1,604.18	332	Discrepancy 09/2017 During servoactuators assays with hydraulic mule, there is no indication of main rotor servo in the EDUI. According to Fault Code 6731-4, requires replacement of the blue and red servos	Removed: Servoactuator assy, red N/P 109-0110-42-134 N/S 4266 Note 2 4.3/TSO NEW. Servoactuator assy, blue Note 2 T.T.1269.8 ht/TSO 459.9 hr. Installed: Red N/S Note 2 T.T. 1426.8 Note 2 and Blue N/S 813, TT 1813.7/TSO 0.0		c) due to lack of indication in EDUI	c) there is no indication in EDUI	The discrepancy is detected at T.T. 1,478.1 hours (March 23, 2017) concludes at T:T: 1,604: 18 hours (July 3, 2017)
12	Without W.O MAR 23, 2017 Note 1	1,604.18	N/T	Discrepancy 09/2017 During friction adjustment work of the yellow servo actuator, mechanical damage was found in the lower bearing, it requires	Spherical bearing assy N/P 28007GR103		Mechanical damage		The discrepancy is detected at T.T. 1,478.1 hours (Mar 23, 2017) ends at T: T: 1,604: 18 hours (Jul 3, 2017)

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[Illegible Signature]

[Illegible Signature]

Work orders findings, records, stickers, component installation, etc. XA-BON N/S 22174 HELICOPTER

Item	W. O. Technical Date	Total A/C Time	Folio	Discrepancy	Component	Frequency	Described damage		Observations
						a) Time b) Calendar time	a) TLV b) Out of Limits c) Others	a) Requirements b) Causes c) Lacks external workshop information	
13	Without W.O 2017/July 3, 2017 Note 1	1,604.18	N/T	Discrepancy 13/2017 during daily inspection, axial play was detected in the rotary scissors at maximum limits (0.18 inch) according to MM REF OB-A-62-31-02-00A-281A-A. Requires replacement of bushings.	Removed: Half-Scissors Rotating N/P 109-8118-16-3 Installed: Half Scissor: Assy, Rotating N/P 109-0134-10-105				The discrepancy is detected at T.T. 1,483.9 hours (Mar 28, 2017) concluded at T.T. 1,604:18 hours (Jul 3, 2017). The discrepancy is closed 121 hours later.
14	Without W.O Mar 28, 2017 Note 1	1,604.18	N/T	Discrepancy 14/2017. By flight report, engine No.1, had stall and T.O.T. difference. On the recommendation of the P&W technical representative, a baroscopic inspection is suggested.	Engine Nº 1			External workshop	The discrepancy is detected at T.T. 1,483.9 hours (Mar 28, 2017) concluded at T.T. 1,604:18 hours (Jul 3, 2017). The discrepancy is closed 121 hours later.
15	Without W.O Mar 28, 2017 Note 1	1,604.18	N/T	Discrepancy 15/2017, During discrepancy 14/2017. Carbon residues were detected in a fuel discharge nose.	Engine Nº 1				The discrepancy is detected at T.T. 1,483.9 hours (Mar 28, 2017) concluded at T.T. 1,604:18 hours (Jul 3, 2017). The discrepancy is closed 121 hours later.

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Work orders findings, records, stickers, component installation, etc. XA-BON N/S 22174 HELICOPTER

Item	W. O. Technical Date	Total A/C Time	Folio	Discrepancy	Component	Frequency	Described damage		Observations
						a) Time b) Calendar time	a) TLV b) Out of Limits c) Others	a) Requirements b) Causes c) Lacks external workshop information	
16	Without W.O Mar 30, 2017 Note 1	1,604.18	N/T	Discrepancy 16/2017. During discrepancy 14/2017, traces of carbon were found in a fuel injector. Injector replacement.	Engine Nº 1 I Inyector N/P 3056042-02 fuel nozzle hybrid				The discrepancy is detected at T.T. 1,486.6 hours (Mar 30, 2017) concluded at T.T. 1,607:05 hours (Jul 17, 2017). The discrepancy is closed 121 hours later.
17	Without W.O Mar 30, 2017 Note 1	1,604.18	N/T	Discrepancy 17/2017 During discrepancy 14/2017. Videoscopic inspection of engine No. 1	Engine Nº 1			External workshop	The discrepancy is detected at T.T. 1,486.6 hours (Mar 30, 2017) concluded at T.T. 1,607:05 hours (Jul 03, 2017). The discrepancy is closed 121 hours later.
18	Without W.O May 29, 2017 Note 1	1,556.40	NT	Discrepancy 20/2017 EDU No. 2 is sent to scripts Channel B and shows IDS. EDU No. 2 is found to be damaged. Requires replacement.	EDU Nº 2 Removed. N/P 109-0900-76-2A01 n/s 090812 Note 2 16051472		c) it is sent to scripts channel B and shows label IDS		The discrepancy is detected at T.T. 1,556.4 hours (Mar 29, 2017) concluded at T.T. 1,604:18 hours (Jul 14, 2017). The discrepancy is closed 121 hours later.

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Blvd Adolfo Lopez Mateos 1990, Col. Los Alpes, Alvaro Obregon. ZC 01010, Mexico City. Phone: 01 (55) 5723 9300

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Work orders findings, records, stickers, component installation, etc. XA-BON N/S 22174 HELICOPTER

Item	W. O. Technical Date	Total A/C Time	Folio	Discrepancy	Component	Frequency	Described damage		Observations
						a) Time b) Calendar time	a) TLV b) Out of Limits c) Others	a) Requirements b) Causes c) Lacks external workshop information	
19	Without W.O Jun 07, 2017 / Jul 14 Note 1	1,579.53		Discrepancy 21/2017 Due to flight report (jumps in the cycle during straight and level flight) when removing the S.A.S. switch. No.1 said jump is resolved, the system was inspected and a damaged vertical gyro No. 1 was found. Requires replacement.	Vertical Gryo was removed. Note 060-11 N/S 09-0448, 08-0399 was installed		Jumps in the cycle during straight and level flight		The discrepancy is detected at T.T. 1,578.56 hours (Jun 07, 2017) concluded at T.T. 1,604:18 hours (Jul 14, 2017). The discrepancy is closed 25 hours later.
20	Without W.O Aug 01, 2017 Note 1	1,623.51	N/T	Discrepancy 24/2017 when testing the hydraulic system with engines running, a knocking was heard in the flight controls area. The system was inspected and the system accumulator No.2 was found with low pressure. It require either replacement or valve filling.	Valve replacement was not required.		Knocking in the flight control area		The discrepancy is detected on Aug 01, 2017 (1,623.51 hours) concluded at T.T. 1,624:42 hours (Aug 03, 2017).

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Blvd Adolfo Lopez Mateos 1990, Col. Los Alpes, Alvaro Obregon. ZC 01010, Mexico City. Phone: 01 (55) 5723 9300
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Work orders findings, records, stickers, component installation, etc. XA-BON N/S 22174 HELICOPTER

Item	W. O. Technical Date	Total A/C Time	Folio	Discrepancy	Component	Frequency	Described damage		Observations
						a) Time b) Calendar time	a) TLV b) Out of Limits c) Others	a) Requirements b) Causes c) Lacks external workshop information	
21	Without W.O Sep 08, 2017 It was cancelled and the discrepancy 30/2017 was created Note 1	1,668.13	N/T	Discrepancy 28/2017, by flight report (it has abrupt movements in the roll axis during its straight and level flight) when removing the S.A.S. No.2 Switch said movement is resolved. An inspection of the system was performed and the vertical gyro No. 2 was found to require replacement.	Vertical gyro N/P 501-1210-01		It has sudden movements in the roll axis during its straight and level flight.		It was cancelled and the 030/2017 discrepancy was created.
22	Without W.O Sep 18, 2017 Note 1	1,677.47	N/T	Discrepancy 30/2017. By flight report the aircraft occasionally deviates to the left with the flight director engaged: Operational tests were carried out in accordance with MM REF OB -A-22-11-00-00A-340A-A. A linear actuator of the roll axis is found damaged. Requires replacement.	Linear electromechanical actuator. Replacement N/S Note 2 Installed Note 2		Occasionally deviates to the left with the flight director engaged.		The discrepancy is detected on Sep 18, 2017 (1,677.47 hours) concluded on Oct 19, 2017 (1,719.32 hours).

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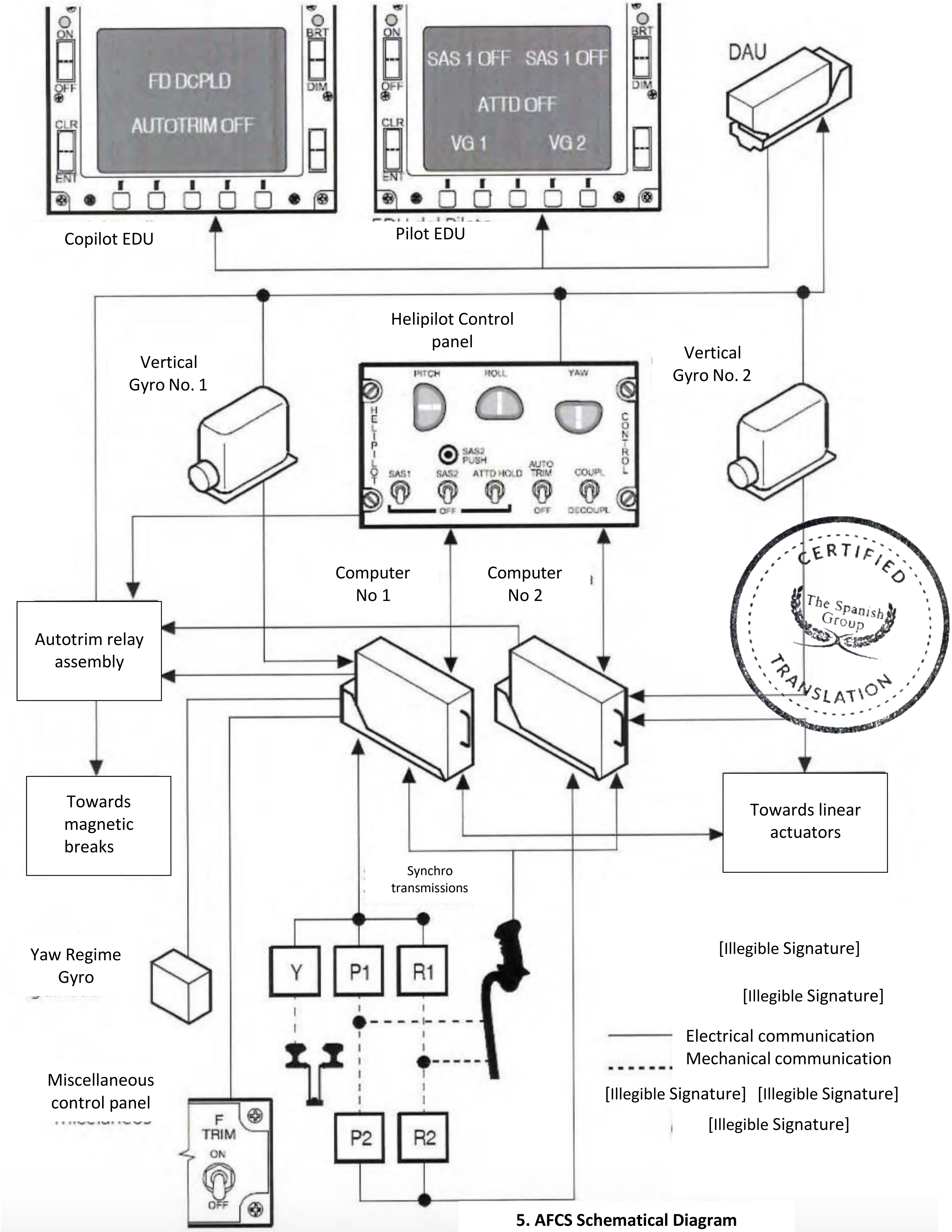
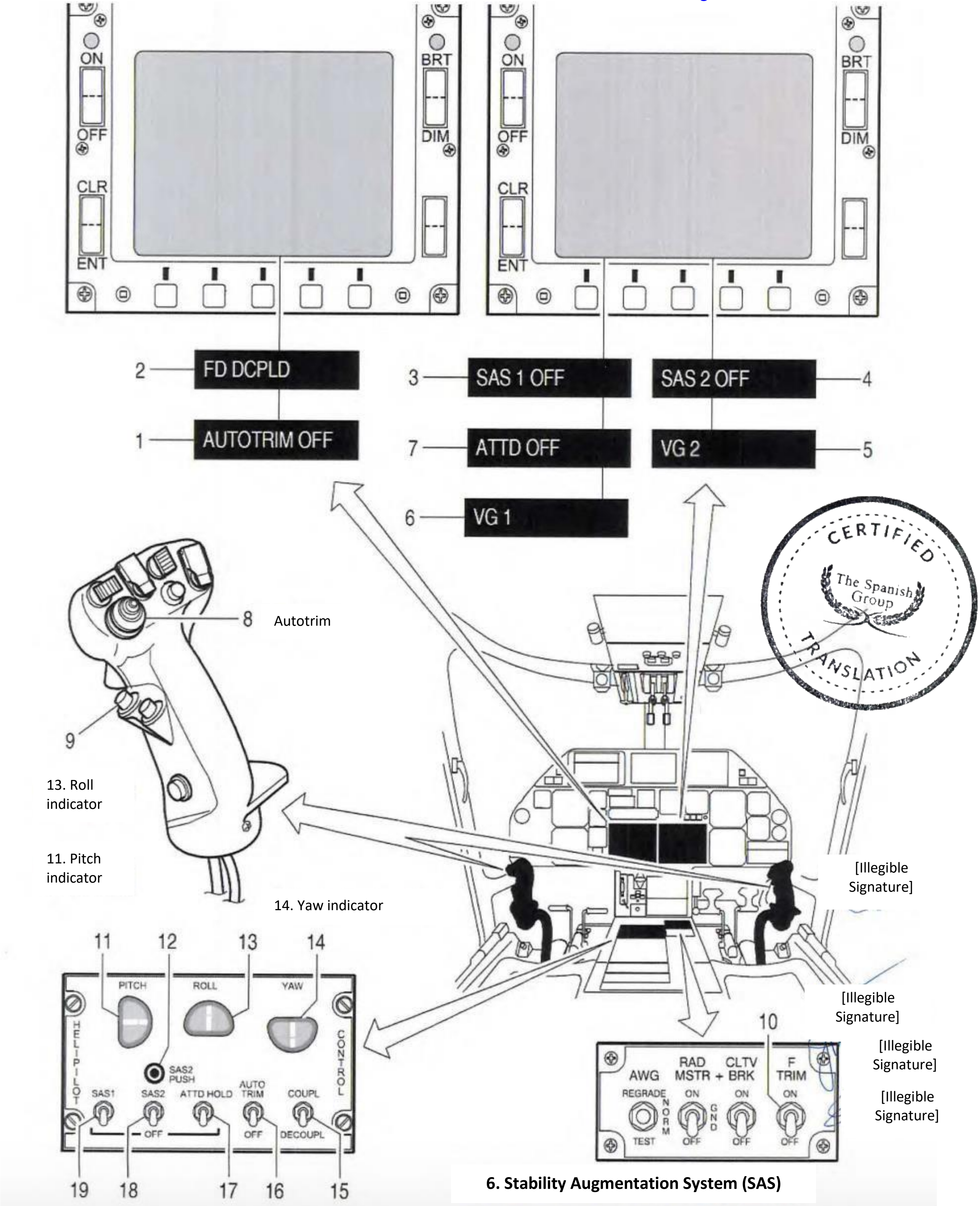
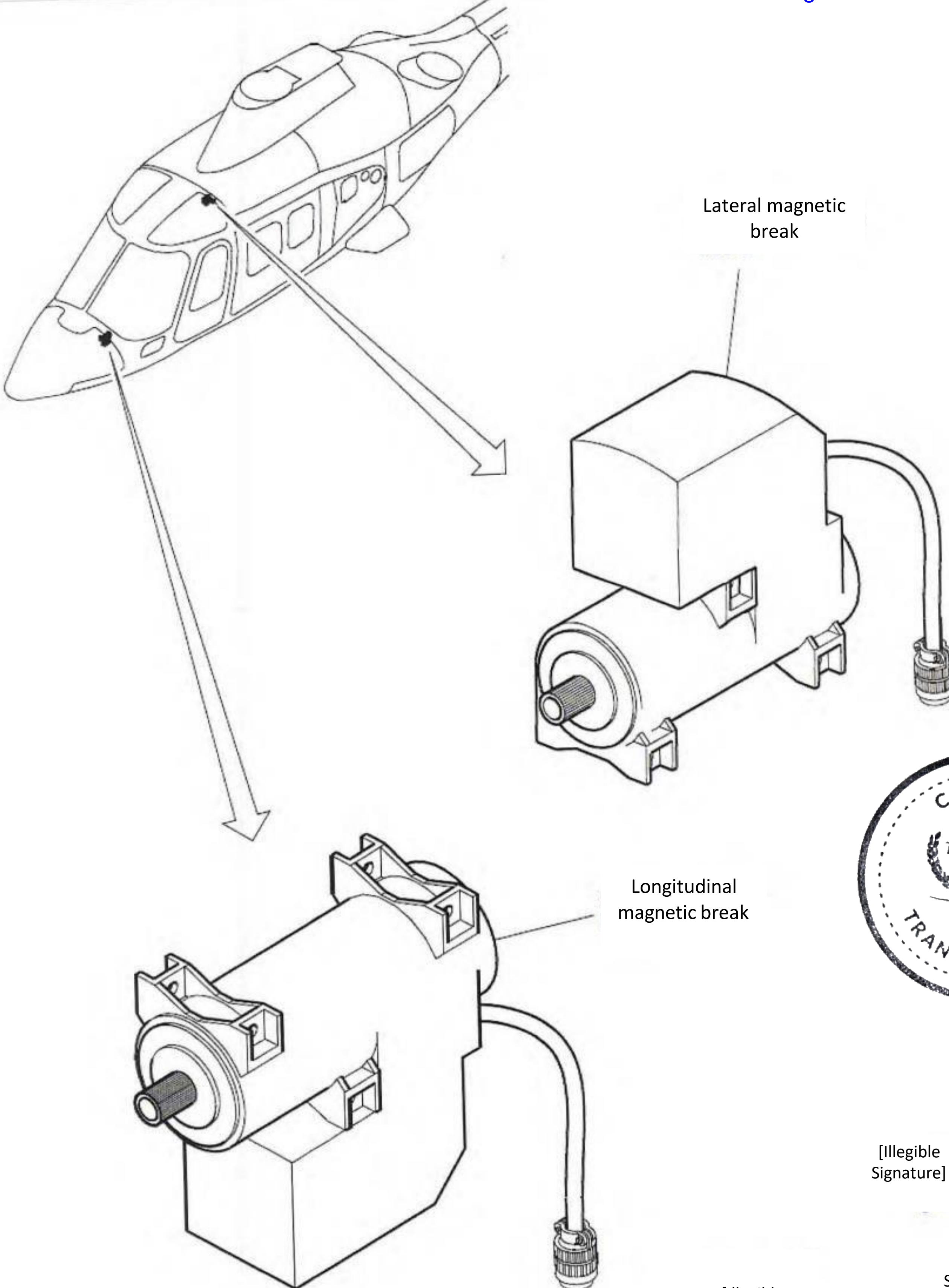


5. AFCS Schematical Diagram



6. Stability Augmentation System (SAS)



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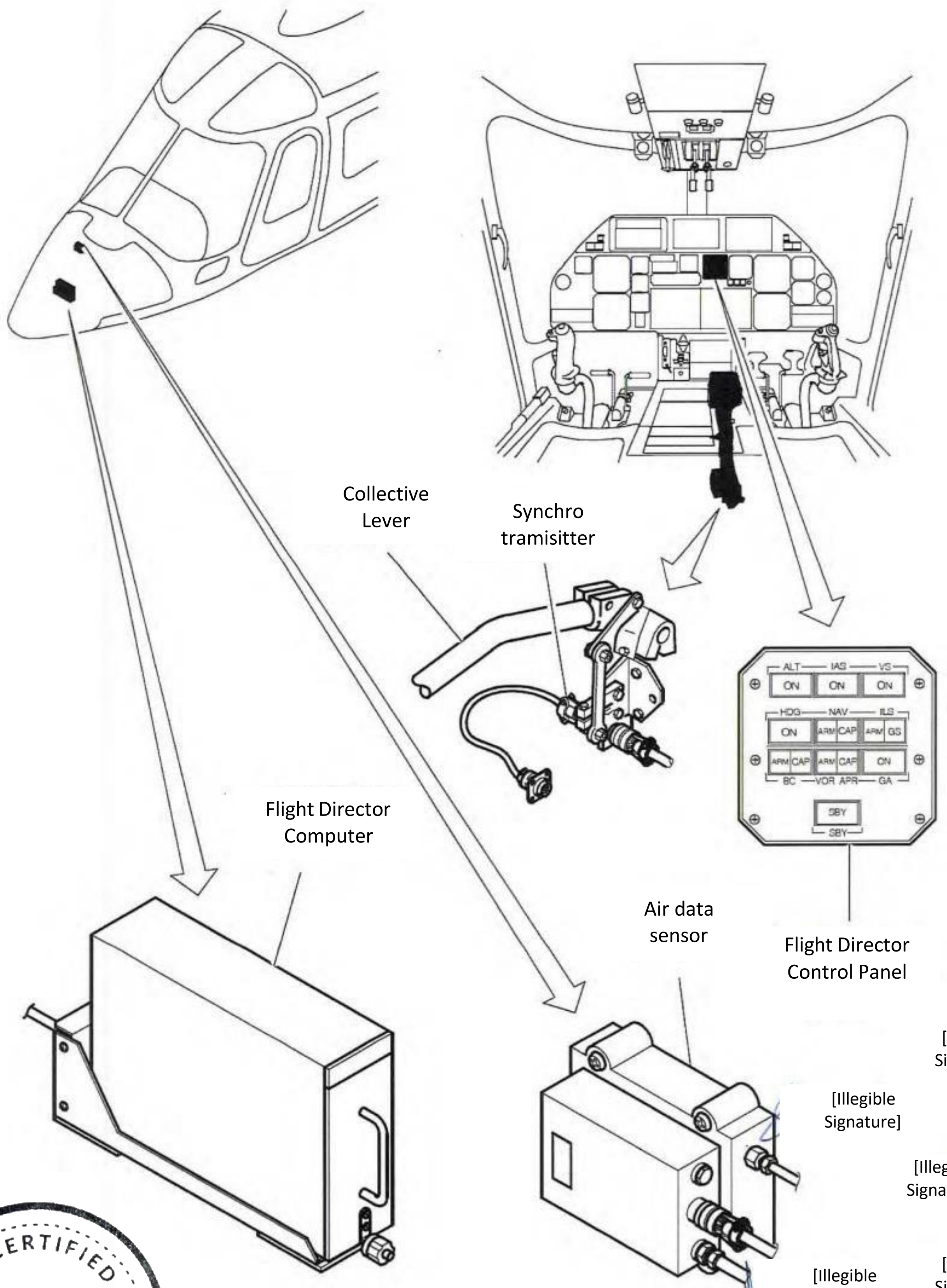
7. Autotrim System



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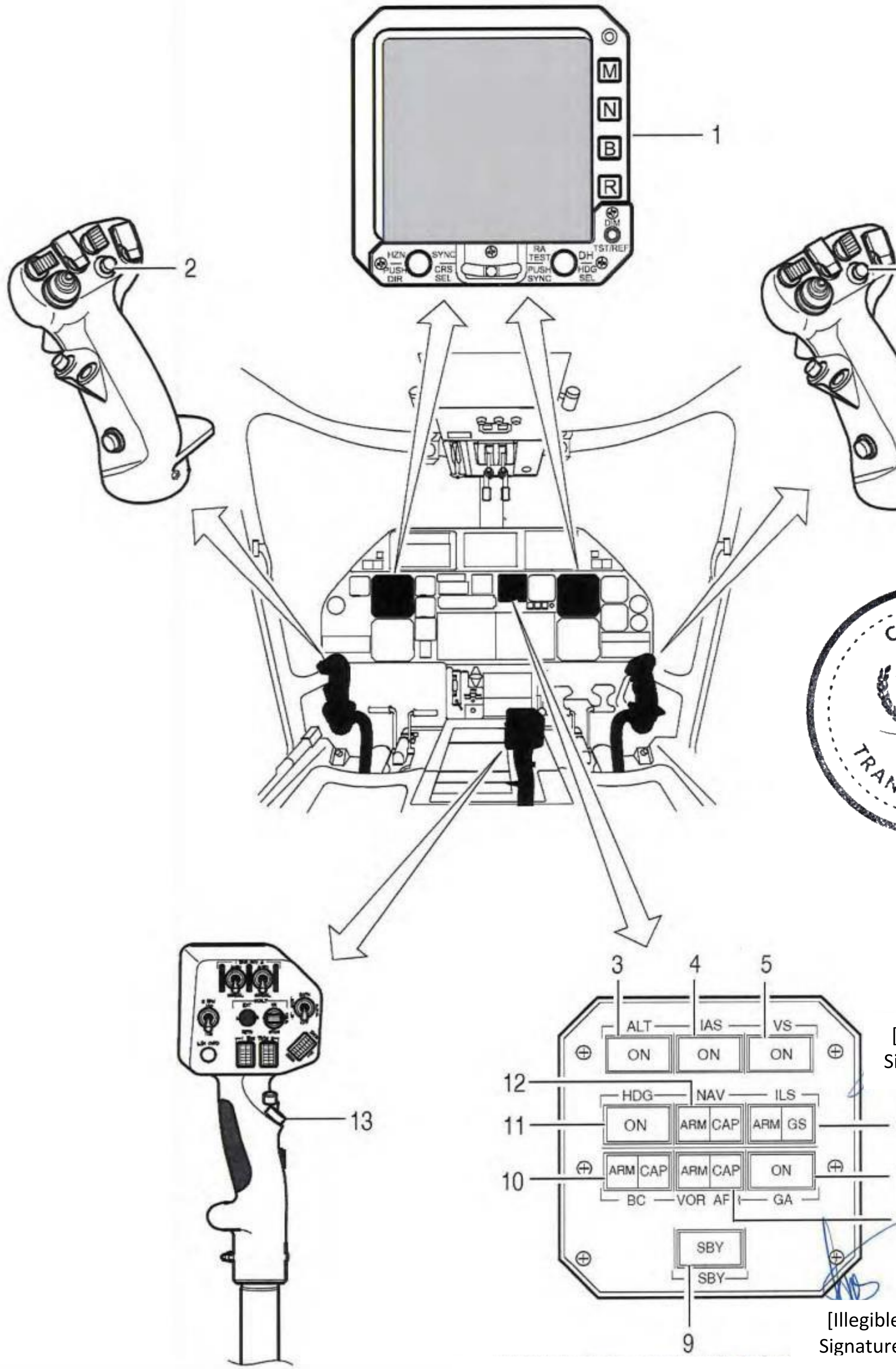
8. Flight Director System



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9. Flight Director Control Panel

[Logo: SAASA] SERVICIOS AEREOS DEL ALTIPLANO, S.A. DE C.V. Log Book **Nº 421**

[Illegible Signature]

AIRCRAFT: AGUSTA, A109S	PILOT: Note 1	LIC: Note 1	ADVISER:	LIC:
MANIFACURING YEAR: 2010	COPILOT: Note 1	LIC: Note 1	FLIGHT CLASS:	
SERIES NO: 22174				
ID: XA-BON	COMMANDER'S SIGNATURE: Note 1		CONTRACT No:	

ROUTE:	UTC HOUR		FUEL	DATE: SEP 7, 2017	TIME CONTROL				
	TAKE OFF/LANDING	DEPARTURE/ARRIVAL							
FROM: LC	23:06	23:04	260	PASSENGERS	FROM:	PRIOR LOGBOOK	THIS LOGBOOK	REAL TIME	LAST MAJOR REPAIRMENT
TO: BC	23:39	23:41	147						
PARTIAL	FLIGHT TIME: 00:33	WEDGE TIME: 00:37	113	2	BASIC BODY	T.T.: 1667:40	00:33	1668:13	
FROM:				PASSENGERS		T.U.R.M.: N/A			
TO:					MOTOR Nº 1: PRATT & WHITNEY PW207C NS: PCE-BH-0434	T.T.: 1667:40	00:33	1668:13	
PARTIAL	FLIGHT TIME:	WEDGE TIME:				T.U.R.M.: N/A			
FROM:				PASSENGERS	MOTOR Nº 2: PRATT & WHITNEY PW207C NS: PCE-BH-0499	T.T.: 1425: 23	00:33	1425:56	
TO:						T.U.R.M.: N/A			
PARTIAL	FLIGHT TIME:	WEDGE TIME:			1ST CYCLE	7522	1	7523	
FROM:				PASSENGERS					
TO:					2ND CYCLE	356	1	357	
PARTIAL	FLIGHT TIME:	WEDGE TIME:							
TOTAL	00:33	00:37	113	2	LANDING	6623	1	6624	

MOTOR READINGS		N 1	ITT	N 2	FLOW	OIL PRESS	OIL TEMP	BATTERY TEMP	MTOW	FLIGHT HEIGHT LEVEL	OAT	MACH IAS	ALTIMETER
1ST SECTION	MOTOR Nº 1												LH RH STBY
	MOTOR Nº 2												
2ND SECTION	MOTOR Nº 1												LH RH STBY
	MOTOR Nº 2												
3RD SECTION	MOTOR Nº 1												LH RH STBY
	MOTOR Nº 2												
4TH SECTION	MOTOR Nº 1												LH RH STBY
	MOTOR Nº 2												

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	AIRSHIP	MAINTENANCE REPORTS	LOGBOOK				
	AGUSTA A109S						
	OBSERVATIONS/REPORTS	REPORT CORRECTIONS	DATE	BASE	MECHANIC, SIGNATURE AND LICENSE NO.		
	DATE:						

No.		OBSERVATIONS/REPORTS	RELEASE CATEGORIES UNDER M.E.L.	DATE	BASE	MECHANIC, SIGNATURE AND LICENSE NO.
		DEFERRED UNDER M.E.L.				

APPLIED AD'S AND SB'S CONTROL

DIRECTIVES / BULLETINS TO GLIDER	DIRECTIVES TO MOTORS		BULLETINS TO MOTOR	
	POS 1	POS 2	POS 1	POS 2

IRREGULARITIES REPORT

No		IRREGULARITIES REPORT	IRREGULARITIES CORRECTION	DATE	BASE	MECHANIC'S SIGNATURE AND LIC. Nº

ENGINE OIL CHANGE

	1ST SECTION	2ND SECTION	3RD SECTION	4TH SECTION

UNIT CHANGE REPORT

UNIT	PART No.	POS.	SERIAL NO. REMOVED	SERIAL NO. INSTALLED	REASON TO CHANGE	DATE	BASE	MECHANIC SIGNATURE AND LICENSE NO.	I CERTIFY TO HAVE CARRIED OUT THE PRELFIGHT AND POSTFLIGHT INSPECTION, AS WELL AS THE DAILY INSPECTION ACCORDING TO MANUFACTURER'S MANUAL, FINDING IT AIRWORTHY
									NAME, SIGNATURE AND LICENSE NO. OF RESPONSIBLE MECHANIC
	PV- PRELFLIGHT. DS- TAKE OFF. AP- APRIMXATELY AR- START AC ASCEND. PA- STOP			REASON [Illegible Signature]	1. LIFE LIM. [Illegible Signature] 4. SCHEDULE. 7. CONVENIENCE 2. WEARING. 5. BOL OR DIRECT 8. FAILURE				

[Logo: SAASA] SERVICIOS AEREOS DEL ALTIPLANO, S.A. DE C.V. Log Book Nº 434

AIRCRAFT: AGUSTA, A1095	PILOT: Note 1	LIC: Note 1	ADVISER:	LIC: [Illegible Signature] [Illegible Signature]
MANIFACURING YEAR: 2010	COPILOT: Note 1	LIC: Note 1	FLIGHT CLASS:	
SERIES NO: 22174				
ID: XA-BON	COMMANDER'S SIGNATURE: Note 1		CONTRACT No: ______________________	

[Illegible Signature]

ROUTE:	UTC HOUR		FUEL	DATE: SEP 14, 17	TIME CONTROL				
	TAKE OFF/LANDING	DEPARTURE/ARRIVAL							
FROM: PBC	20:40	20:38	372	PASSENGERS	FROM:	PRIOR LOGBOOK	THIS LOGBOOK	REAL TIME	LAST MAJOR REPAIRMENT
TO: PBC	20:49	20:51	330						
PARTIAL	FLIGHT TIME: 00:09	WEDGE TIME: 00:13	42	-	BASIC BODY:	T.T.: 1676:47	01:00	1677:47	
FROM: PBC	21:30	21:28	330	PASSENGERS		T.U.R.M.: N/A			
TO: PBC	21:34	21:36	300		MOTOR Nº 1: PRATT & WHITNEY PW207C NS: PCE-BH-0434	T.T.: 1676:47	01:00	1677:47	
PARTIAL	FLIGHT TIME: 00:04	WEDGE TIME: 00:08	30	-		T.U.R.M.: N/A			
FROM: PBC	22:10	22:08	300	PASSENGERS	MOTOR Nº 2: PRATT & WHITNEY PW207C NS: PCE-BH-0499	T.T.: 1434: 30	01:00	1435:30	
TO: MEX	22:29	22:31	284			T.U.R.M.: N/A			
PARTIAL	FLIGHT TIME: 00:19	WEDGE TIME: 00:23	16	1	1ST CYCLE	7562	5	7567	
FROM: MEX	03:00	02:58	284	PASSENGERS					
TO: HAN	03:28	03:30	146		2ND CYCLE	400	3	403	
PARTIAL	FLIGHT TIME: 00:28	WEDGE TIME: 00:32	138	-					
TOTAL	01:00	01:16	226	1	LANDING	6506	4	6570	

MOTOR READINGS		N 1	ITT	N 2	FLOW	OIL PRESS	OIL TEMP	BATTERY TEMP	MTOW	FLIGHT HEIGHT LEVEL	OAT	MACH IAS	ALTIMETER
1ST SECTION	MOTOR Nº 1												LH RH STBY
	MOTOR Nº 2												
2ND SECTION	MOTOR Nº 1												LH RH STBY
	MOTOR Nº 2												
3RD SECTION	MOTOR Nº 1												LH RH STBY
	MOTOR Nº 2												
4TH SECTION	MOTOR Nº 1												LH RH STBY
	MOTOR Nº 2												

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SERVICIOS AEREOS DEL ALTIPLANO, S.A. DE C.V. [Illegible Signatures]

ID:	AIRSHIP	MAINTENANCE REPORTS	LOGBOOK			
BON	AGUSTA A109S					

		OBSERVATIONS/REPORTS	REPORT CORRECTIONS	DATE	BASE	MECHANIC, SIGNATURE AND LICENSE NO.	
NAME, SIGNATURE		DATE:					
							[Illegible Signatures]

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DEFERRED UNDER M.E.L.

		OBSERVATIONS/REPORTS	RELEASE CATEGORIES UNDER M.E.L.	DATE	BASE	MECHANIC, SIGNATURE AND LICENSE NO.	

APPLIED AD'S AND SB'S CONTROL

DIRECTIVES / BULLETINS TO GLIDER	DIRECTIVES TO MOTORS		BULLETINS TO MOTOR	
	POS 1	POS 2	POS 1	POS 2

IRREGULARITIES REPORT

		IRREGULARITIES REPORT	IRREGULARITIES CORRECTION	DATE	BASE	MECHANIC'S SIGNATURE AND LIC. Nº

ENGINE OIL CHANGE

	1ST SECTION	2ND SECTION	3RD SECTION	4TH SECTION
ENGINE Nº 1				
ENGINE Nº2				
APU				

UNIT CHANGE REPORT

UNIT NAME	PART No.	POS.	SERIAL NO. REMOVED	SERIAL NO. INSTALLED	REASON TO CHANGE	DATE	BASE	MECHANIC SIGNATURE AND LICENSE NO.	I CERTIFY TO HAVE CARRIED OUT THE PREFLIGHT AND POSTFLIGHT INSPECTION, AS WELL AS THE DAILY INSPECTION ACCORDING TO MANUFACTURER'S MANUAL, FINDING IT AIRWORTHY
									Note 1
									NAME, SIGNATURE AND LICENSE NO. OF RESPONSIBLE MECHANIC
REPORT REFERRAL	PV- PREFLIGHT. DS- TAKE OFF. AP- APRIMXATELY AR- START AC ASCEND. PA- STOP CA- [ILLEGIBLE]. CR: CRUISE. O-OTHER			REASON FOR CHANGE	1. LIFE LIM. 4. SCHEDULE. 7. CONVENIENCE 2. WEARING. 5. BOL. OR DIRECT 8. FAILURE 3. INSPECTION 6. EVENT. 9. OTHER				Note 1 DATE: 09/16/17

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[Logo: Rotor Flight Services]

					DISCREPANCY No. 28/2017
AIRCRAFT DATA					
MODEL	A109S	SERIES	22174	ID	XA-BON
DATE	September 8, 2017	CREATED BY:	Note 1	TIME OF OCCURRENCE	1668:13 HRS
DISCREPANCY DESCRIPTION					
BY FLIGHT REPORT (IT HAS ABRUPT MOVEMENTS IN THE ROLL AXIS DURING STRAIGHT AND LEVEL FLIGHT) WHEN REMOVING THE S.A.S No. 2 SWITCH SAID MOVEMENT IS RESOLVED. INSPECTION OF THE SYSTEM WAS PERFORMED AND IT WAS FOUND THAT VERTICAL GYRO NO. 2 WAS DAMAGED AND REQUIRED REPLACEMENT.					
OBSERVATIONS			AUTHORIZED BY		
Note 3			Note 1		

CONSUMABLES AND PARTS

Nº	PIECE Nº / SERIAL Nº	DESCRIPTION	REQUIRED QUANTITY	PURCHASE ORDER Nº	WAREHOUSE VAUCHER Nº
1	Note 2	VERTICAL GYRO	01		
2					
3					
4					
5					
6					
7					
8					
9					

CORRECTIVE ACTION			
Cancelled, discrepancy 30/2017 was created.			
ESTIMATED TIME:	2 HRS	REAL TIME:	[Illegible Signature]
CARRIED OUT BY:		CONCLUSION DATE	
INSPECTED BY:		CONCLUSION TIME	

[Illegible Signature] [Illegible Signature]
[Illegible Signature] [Illegible Signature]

Note 1

I received the discrepancy on 09/05/2017
Note 1

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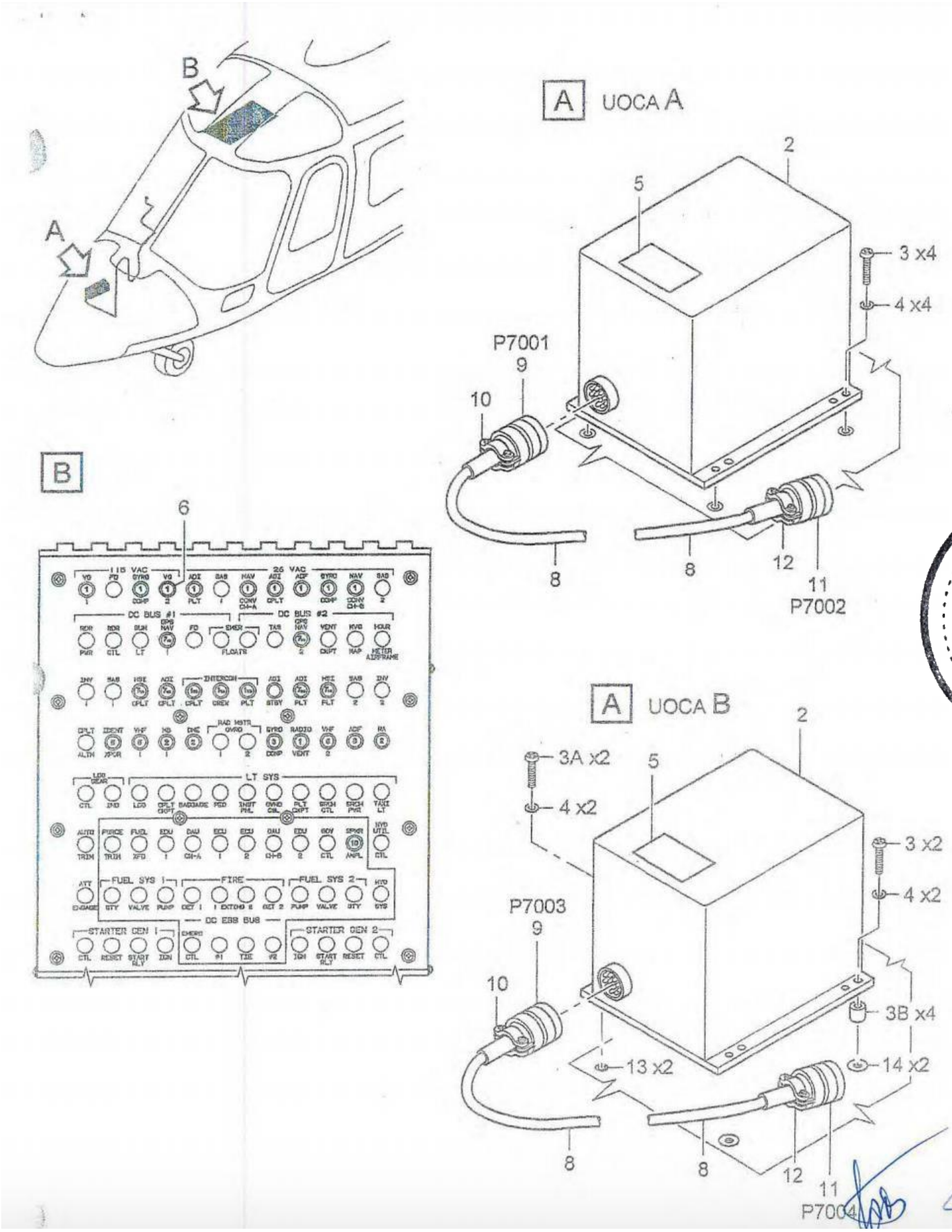
RFS-DIS-REV 2



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ICN-0B-A-221100-G-00001-00310-A-04-1

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FIGURE 2. NUMBER 2 VERTICAL GYROSCOPE SYSTEM

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Actuator instl, cyclic and tail rotor pitch control Illustrated Parts Data – IPD

FIG ITEM	PART NUMBER……. NSN……..	DESCRIPTION 1 2 3 4 5 6 7 8 9	**UOCA.. MVEFFECT..	I C Y	QNHA UI	SMR..
03	Note 2 [redacted]					
-0			G		REF	XC
-1			G		REF	AFOFF
-2			G		0001 EA	PAOFF
3			G		0001 EA	PAFZZ
4			G		REF	XA
-5			G		0001 EA	PAOFF
6			G		0001 EA	PAFZZ
7			G		REF	XA
-8			G		0001 EA	PAOZZ
9			G		0002 EA	PAOZZ
10			G		0001 EA	PAOZZ
11			G		0001 EA	PAOZZ
11			G		AR EA	PAOZZ
11			G		AR EA	PAOZZ
12			G		0001 EA	PAOZZ
13			G		0001 EA	PAOZZ
14			G		0002 EA	PAOZZ
15			G		0002 EA	PAOLD
16			G		0002 EA	PAOZZ
-17			G		REF	AFOFF
-18			G		0001 EA	PAOFF
19			G		0001 EA	PAFZZ
20			G		REF	XA

[Illegible Signature] [Illegible Signature] [Illegible Signature]
[Illegible Signature] [Illegible Signature]

[Logo: Rotor Flight Services]

DISCREPANCY No. 030/2017					
AIRCRAFT DATA					
MODEL	A109S	SERIES	22174	ID	XA-BON
DATE	September 18, 2017	CREATED BY:	Note 1	TIME OF OCCURRENCE	1677:47 HRS
DISCREPANCY DESCRIPTION					
BY FLIGHT REPORT. AIRCRAFT OCCASIONALLY DEVERSES HEADING TOWARDS THE LEFT WITH FLIGHT DIRECTOR ENGAGED. OPERATIONAL TESTS WERE PERFORMED IN ACCORDANCE WITH MM REF 0B-A-22-11-00- 00A-340A-A. A ROLL AXIS OF THE LINEAR ACTUATOR WAS FOUND TO BE DAMAGED. IT REQUIRES REPLACEMENT.					
OBSERVATIONS			AUTHORIZED BY		
			Note 1		
CONSUMABLES AND PARTS					

Nº	PIECE Nº / SERIAL Nº	DESCRIPTION	REQUIRED QUANTITY	PURCHASE ORDER Nº	WAREHOUSE VAUCHER Nº
1	4012373-909	ACTUATOR, ELECTROMECHANICAL, LINER	01		
2					
3					
4					
5					
6					
7					
8					
9					

CORRECTIVE ACTION			
Linear actuator was replaced according to MM REF OB-A-22-11-04- 00A-520A-A, 0B-A-22-11-04-00A-720A-A resulting in airworthy conditions. S/N 0909L506 was removed, S/N 99124118 was installed.			
ESTIMATED TIME:	2 hours	REAL TIME:	2 hours
CARRIED OUT BY:	Note 1	CONCLUSION DATE	Oct 19, 2017
INSPECTED BY:	Note 1 [Illegible Signature]	CONCLUSION TIME	1719:32

[Illegible Signature]

[Illegible Signature] [Illegible Signature] [Illegible Signature] [Illegible Signature]

Calle 3 Modulo I
Toluca International Airport
Toluca, Mexico, ZC 50200
Phone: +52 722 2770541

RFS-DIS-REV 2
[Illegible Signature]

Actuator instl, cyclic and tail rotor pitch control Illustrated Parts Data – IPD

FIG ITEM	PART NUMBER……. NSN……..	DESCRIPTION 1 2 3 4 5 6 7 8 9	**UOCA.. MVEFFECT..	I C Y	QNHA UI	SMR..
03	Note 2					
-0					REF	XC
-1					REF	AFOFF
-2					0001 EA	PAOFF
3					0001 EA	PAFZZ
4					REF	XA
-5					0001 EA	PAOFF
6					0001 EA	PAFZZ
7					REF	XA
-8					0001 EA	PAOZZ
9					0002 EA	PAOZZ
10					0001 EA	PAOZZ
11					0001 EA	PAOZZ
11					AR EA	PAOZZ
11					AR EA	PAOZZ
12					0001 EA	PAOZZ
13					0001 EA	PAOZZ
14					0002 EA	PAOZZ
[HW: 01 piece] 15					0002 EA	PAOZZ
16					0002 EA	PAOLD
-17					REF	AFOFF
-18					0001 EA	PAOFF
19					0001 EA	PAFZZ
20					REF	XA

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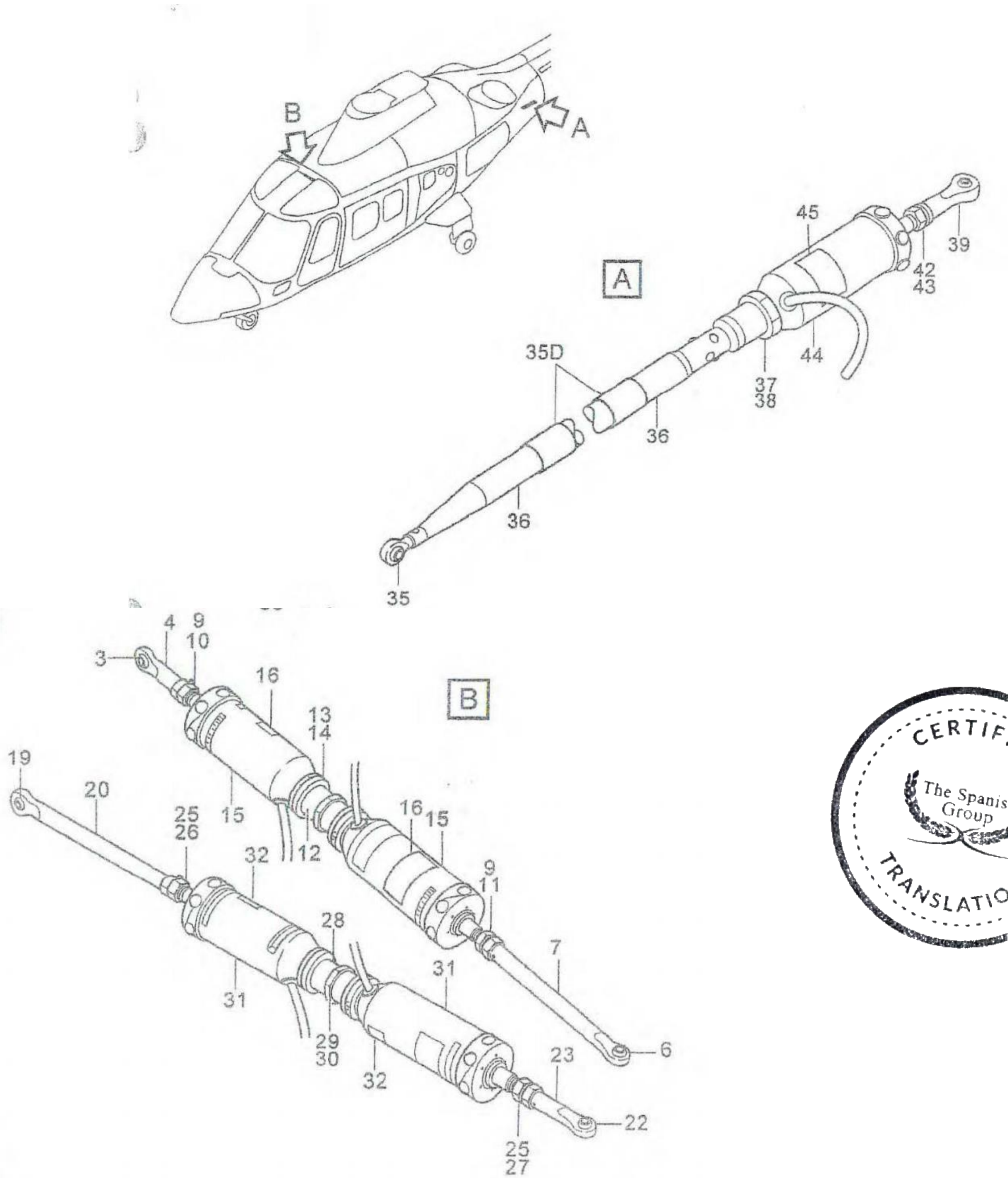

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ICN-OB-A-221100-G-00001-00310-A-04-1

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FIGURE 1. ACTUATOR INSL, CYCLIC AND TAIL ROTOR PITCH CONTROL

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[Illegible Signature] [Illegible Signature]

eluniversal.com.mx/columna/hector-de-mauleon/nacion/la-pieza-clave-del-helicopterazo-de-puebla

	EL UNIVERSAL	ENGLISH	PHOTOGRAPHS	VIDEO	GRAPHICS	MXM	
[Google Ads]	[Photograph] HECTOR DE MAULEON Writer and journalist SAVE FACEBOOK TWITTER GOOGLE+ OTHERS TOPICS Hector de Mauleon piece Key helicopter Puebla	that the first information indicated "03 calcined people" Navigation Services Personnel in the Mexican Air Space (Seneam) confirmed, at 4:10 p.m., that the helicopter was providing air taxi service to the **government of Puebla**. At 4:20 p.m., the Second Section of the Secretariat of Navy reported that the helicopter's ELT radio beacon (Emergency Locator Transmitter, the radio transmitter device used in cases of emergency) had been activated nine minutes after takeoff, at 2:43 p.m. According to the coordinates, the collapse would have occurred in the municipality of Coronango, four kilometers east of the **Puebla airport.** Elements of the Investigation Division called the senator's office, and **former governor of Puebla, Rafael Moreno Valle**. There was no answer. From that moment, and until 4:54 p.m. - according to the report - communication was sought with the office of the **governor of the state of Puebla, Martha Erika Alonso**. No one answered the call. At 4:25 p.m., the Regional Security Division of the Federal Police reported that they had reached the area of the accident. **The helicopter was "90%" calcined.** "They were seen",				[Banner]	[Google Ads]

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https://www.e-consulta.com/opinion/2019-02-11/mas-certezas-que-dudas-sobre-el-helicoptero-caido

SECTIONS	POINT OF VIEW	SHOW BUSINESS	MUNICIPALITIES	
to contact the aircraft pilots on nine times. There was no response, the official report was: "The communication was lost."				[Banner] [Google Ads]

-The first report of the Federal Police established "03 calcined people." The Mexican Air Space Navigation Services office (SENEAM) confirmed at 4:10 p.m. that the helicopter provided air taxi service to the Government of Puebla, reported by Hector de Mauleon, an expert in police affairs., in his column “En Tercera Persona” of “El Universal” daily.

-At 4:20 p.m., the Second Section of the General Staff of the Secretariat of Navy reported that the Emergency Locator Transmitter radio beacon, a radio transmitter device used in cases of emergency (ELT), of the helicopter had been activated nine minutes after takeoff, at 2:43 p.m. The radio beacon is a radioelectric route signaling device that consists of a beacon equipped with a transmitter and which broadcasts signals, generally according to a pre-established code.

-According to the coordinates, the crash occurred in the municipality of Coronango, State of Puebla, four kilometers east of the Puebla International Airport.

-Elements of the Investigation Division of the Federal Police called the office of the Senator of the Republic Moreno Valle Rosas, but there was no response. From 2:43 p.m. to 4:54 p.m., they tried to contact the office of the governor of Puebla, Martha Erika Alonso. No one answered the call.

-About the foregoing, it is striking that there was no person on duty at the government offices. Former government officials indicate that it is a gross error of the government not to leave guards in main offices on holidays. Another inexperienced error is that a state president should never travel without a chief deputy, an assistant or an escort.

-At 4:25 p.m., the Regional Security Division of the Federal Police reported that they had reached the area of the accident. The helicopter was calcined "to 90%, 03 calcined bodies were seen", says the report.

-At 5:01 p.m., a Federal Police sub-inspector stationed in San Martin Texmelucan reported that

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[Logo: Secretariat of Communication and Transport] [Logo: Federal Civil Aviation Agency]

Disclaimer

Note 1. Based on Art.68, 116 of the General Law of Transparency and Access to Public Information; 113 Section I of the Law of Transparency and Access to Public Information, the names of the aeronautical technical personnel are eliminated because they are data of natural persons that require their consent for their disclosure.

Note 2 Based on Art. 113 Section II of the Federal Law on Transparency and Access to Public Information, number thirty-eight of the General Guidelines on Classification and Declassification of Information, as well as for the preparation of public versions, the Serial numbers of the aircraft are deleted, as they are unique industrial data of each component or part of the equipment.

Exhibit A

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SECRETARIAT OF COMMUNICATION AND TRANSPORT.
GENERAL DIRECTORATE OF CIVIL AVIATION.
AVIATION ACCIDENT AND INCIDENT ANALYSIS DIRECTORATE.

HELICOPTER ACCIDENT, BRAND AGUSTA, MODEL A1095, SERIAL NUMBER 22174, ID XA-BON, PROPERTY OF SERVICIOS AEREOS DEL ALTIPLANO SA DE CV

[CUT-OFF TEXT] JANUARY 2019
[CUT-OFF TEXT]: NAUTICAL MILES
VARIOUS

MAP NAME: SKETCH OF THE ACCIDENT OF THE XA-BON ACDTARA004/2018MMP9

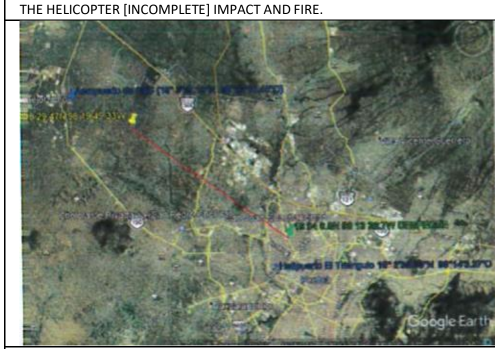
[CUT-OFF TEXT] IN CHARGE: DGAC SCT
[CUT-OFF TEXT] CONSTANTINO TERCERO

[CUT-OFF TEXT] SCT
[CUT-OFF TEXT] CRUZ GARCIA

[CUT-OFF TEXT] SOLIS MORGADO

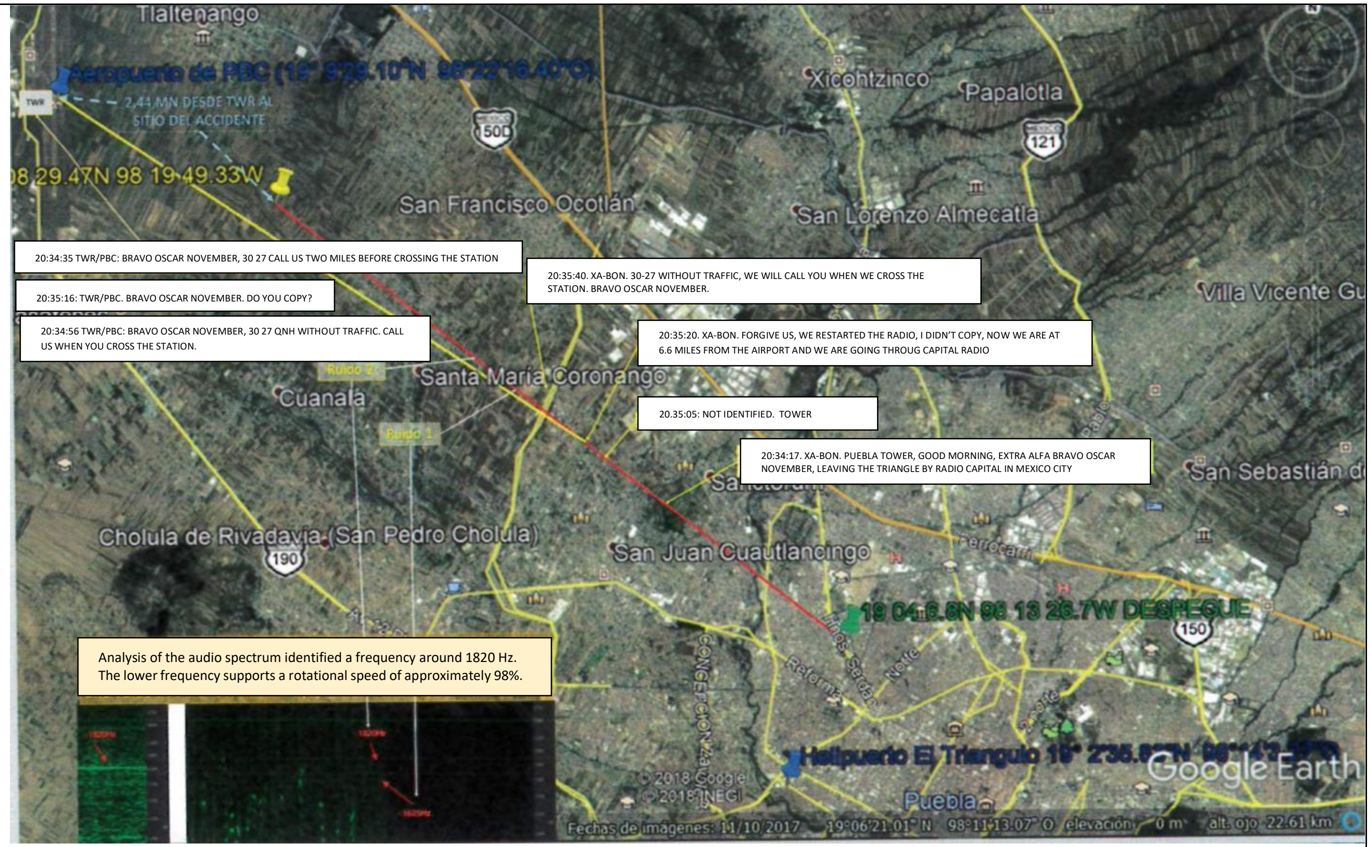
[CUT-OFF TEXT] ANTONIO GARCIA HERNANDEZ

SKETCH OF DECEMBER 24, 2018, AT 14:35 (20:35 UTC), AN HELICOPTER, AGUSTA BRAND, MODEL A1095, SERIAL NUMBER 22174, ID XA-BON, PROPERTY OF SERVICIOS AEREOS DEL ALTIPLANO, SA DE CV, WHEN COVERING THE FLIGHT FROM THE CITY OF PUEBLA TO THE CITY OF [CUT-OFF TEXT], THE VISUAL FLIGHT RULES (VFR) IN CONTROL OF THE HELICOPTER WERE A COMMANDER AND AN [CUT-OFF TEXT] BOTH WITH A HELICOPTER COMMERCIAL LICENSE, IMPACTING ON THE GROUND [CUT-OFF TEXT], WITH FATAL INJURIES TO THE THREE PASSENGERS AND TWO CREW ON BOARD, AND THE HELICOPTER [INCOMPLETE] IMPACT AND FIRE.

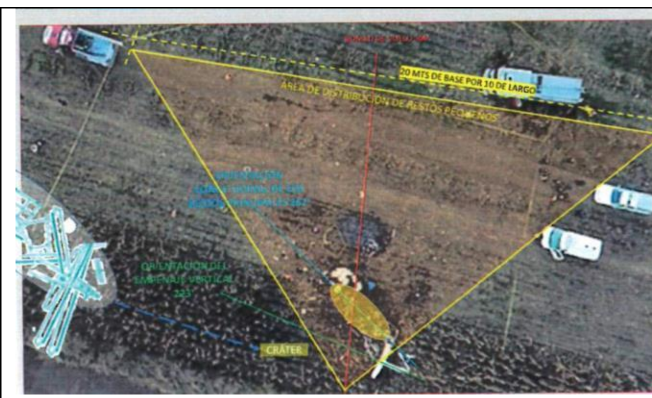


TRAJECTORY OF THE XA-BON WITH FLIGHT COURSE 306.
HELIPORT "EL TRIANGULO" WHICH REPORTED THE CREW OF THE XA-BON THAT STARTED THE DEPARTURE OPERATION FROM COORDINATES 19'04'06.8'N 98'13'26.7'W.
ACCIDENT IN THE COORDINATES 19'08'29.47'N 98'13'49.33'W (ADVANCING 7.45 NM)
PUEBLA INTERNATIONAL AIRPORT (PBC) (REMAINING 2.44 NM FROM THE ACCIDENT SITE)

SEARCH FOR THE 1,394 MT2 MVA



THE XA-BON FELL TO GROUND WITHOUT CONTROL, IMPACTING IN THE REVERSED POSITION, FIRST HITTING ONE OF THE 4 BLADES AGAINST THE GROUND, BURING UP TO 1.8 M, FOLLOWED BY THE REMAINING BLADES, BEGINNING THE MECHANICAL DESTRUCTION OF THE HELICOPTER, FIRST THE COPILOT DOOR AND THE DOOR OF THE PASSENGER SITTING TO THE LEFT IN THE REAR SEATS (IN THE DIRECTION OF THE FLIGHT) FELL OFF, THE OTHER TWO PASSENGERS REMAINED INSIDE THE PASSENGER CABIN AND FINALLY THE CAPTAIN IS EXPELLED DURING THE FINAL TURN OVER ITS VERTICAL AXIS, REMAINING BEHIND THE TWO PASSENGERS WHO WERE EXPELLED AT THE BEGINNING OF THE DISASTER. THE FIRE PRODUCED BY THE IMPACT CONSUMED THE STRUCTURE OF THE HELICOPTER AS WELL AS IMPORTANT ELEMENTS FROM WHICH WOULD HAVE BEEN HEPLFUL TO EXTRACT FLIGHT DATA BEFORE THE IMPACT; THIS HELICOPTER DID NOT HAVE FLIGHT AND VOICE DATA RECORDERS. AS FOR THE COMPONENTS WITH NON-VOLATILE MEMORY, THEY WERE DESTROYED BY IMPACT AND FIRE.



THE XA-BON FLEW 7.45 MN BEFORE IMPACTING AGAINST A PLANTING LAND, THE MAIN REMAINS ORIENTED AT 262º AND THE EMPENNAGE AT 223º. FROM THE ABOVE IT IS OBSERVED THAT THE DISTRIBUTION OF THE REMAINS IS COINCIDENT WITH THE DIRECTION OF THE XA-BON'S FLIGHT.
IT IS DENOTED THAT THE HELICOPTER IMPACTED AGAINST THE GROUND IN A PRACTICALLY REVERSED FLIGHT POSITION, HITTING AGAINST IT AT AN 60º ANGLE, TURNING ON IMPACT CLOCKWISE, PRACTICALLY 260º, CREATING FIRE AS A RESULT OF THE IMPACT. A CRATER OF 5.7 M LONG, 3.3 M WIDE AND 1.2 M DEPTH WAS CREATED, AND LOCATING A BLADE OF THE MAIN ROTOR AT 1.8 M DEPTH. [ILLEGIBLE SIGNATURES]

Exhibit B

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[Coat of Arms of the United Mexican States]

[Logo: AFAC - Federal Civil Aviation Agency]

COMUNICACIONES | AFAC

SECRETARIAT OF COMMUNICATION AND TRANSPORT

Under-Secretariat of Transport
General Directorate of Civil Aviation
Aviation Accident and Incident Analysis Directorate

Content

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Factual report of the inspection of the remains of the engines.

Investigators and experts from the manufacturer identified and recovered the two engines from the accident site, so from March 4 to 8, 2019, at the Pratt & Whitney Canada facilities, located in the City of St. Hubert, Montreal, Canada , the destructive inspection of the motors was carried out, in addition to inspecting the remains they located of the following electronic control components, 2 Electronic Engine Controls (EEC's, Electronic Engine Control) and 2 Data Collection Units (DCU's, Data Collection Unit), which act as non-volatile memory components of the engines, which were very damaged externally, however it was decided to send them to their manufacturers so that the necessary attempts to extract information for the investigation could be made.

The components with non-volatile memory were sent to the following facilities to obtain information related to the operation of the motors, since they have the means to read them:

Engine 1	Engine 2	State
1 DCU (Data Collection Unit)	1 DCU (Data Collection Unit)	They were found destroyed by impact and fire, the openings were made in Safran, Canada, on March 26, 2019
1 Electronic Engine Control (EEC)	1 Electronic Engine Control (EEC)	Destroyed by impact and fire, the openings were made in Collins, USA, on April 18, 2019

1. Inspection result of the left engine.
In the activities carried out at the engine manufacturer's facilities, it was decided to begin inspecting the engine position number one (left), Pratt & Whitney Canada brand, model PW207C, series BH0434, which according to the data provided by the Rotor Flight Services (RFS) Workshop, the engine had the following updated times as of December 25, 2018.

Total time: 2,178.7 hours.
Time since last inspection: 28.1 hours on November 28, 2018.
Total cycles: 9,426 cycles.

All positional references are in relation to viewing the engine from the front and the flow of exhaust gases from the compressor inlet to the exhaust.

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1.1. External condition.
All external pipes and wires were deformed, cut or crushed due to the impact. The gearbox section was separated from the compression section rearward.

The engine also exhibited deformation due to impact and there was a large amount of soot from the post-event fire to which it was exposed. Only a part of the gearbox section was recovered, which was deformed and fractured into several parts.

1.1.1 Compressor inlet.
The compressor housing broke into pieces, which make up about 2/3 of this section. The mesh was found to be deformed and did not cover the area for which it was designed, and the mesh did not show signs of loss of material before impact.

1.1.2. Diffuser.
There was deformation in the two diffuser tubes which is consistent with the deformation found in the gas generator housing located at the 6 o'clock position. At the level of the flange B, the inlet housing was deformed due to the impact located in the

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2 o'clock position, there is presence of post-event soot.

1.1.3. Gas generator housing.
It shows compression deformation at the 2 o'clock position along the housing and impact damage was found at the 6 o'clock position.

1.1.4. Turbine support housing.
The mounting flange shows some bending and four screws fractured at the location of the damage. The rest of the housing is intact.

1.1.5. Exhaust gas duct.
The exhaust duct has minor damage to the bolting flange. The exhaust ducts were crushed due to the impact and were no longer attached to the engine.

1.2. Metal particle detectors (Chip detectors) and filters.
The particle detector was not present in the engine, it fell off due to the impact. The oil filter was not present in the engine, it fell off due to the impact.

1.3. Turbine section.
1.3.1. Power turbine.
All blades were intact and present, with some leading-edge friction (with the stator) and the disc tips showed friction with the cover. There was no apparent damage to the leading edge of the blades.

1.3.2. Power turbine shaft.
The power turbine shaft fractured at the level of the bearing number 3 section. The fracture surface shows a 45-degree angle, which is a sign of overload. There are several friction marks where the shaft showed signs of rotation when making contact with the impeller and the compressor turbine (CT) disc. The observed damage is typical due to rotation at impact.

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1.33. Bearing No. 5.
This bearing rotated freely and also exhibited blackening that is typical of this engine model.

1.3.4. Power turbine cover.
It shows signs of friction along the honeycomb along the entire circumference.

1.3.5. Power turbine stator.
The blades showed no signs of damage. The outer edge of the cover shows evidence of slight contact with the blade decks. The inner cover shows evidence of friction from contact with the CT blades on the decks.

1.3.6. Gas generator turbine compressor.
All blades were present and no damage was observed. The tips of the blades show signs of extensive friction. The lower part inside the platform shows signs of friction with the Power Turbine Stator.

1.3.7. Compressor turbine cover.
It showed signs of heavy contact friction and material transfer between the 4 and 6 o'clock positions and light friction on the rest of the circumference. The cover shows evidence of deposits of molten and re-solidified materials, originated by the friction

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of the CT (compressor turbine) blades.

1.3.8. Compressor turbine stator.
It showed no signs of damage.

1.4. Combustion section.
1.4.1. Combustion chamber.
The combustion chamber darkened due to soot and deformed at the 5 o'clock position due to contact with the oil pressure line to bearing 4.

1.5. Compressor section.
1.5.1. Centrifugal impeller.
Before disassembly the impeller could not be rotated by hand force. After removal of the CT disc this impeller rotated freely. There was damage to the leading edge, as well as material rolled in the opposite direction to the direction of rotation, it is characteristic of typical impact damage. Inductor blades at the front showed strong bending friction in the direction opposite to the rotation direction. The entire impeller blades showed heavy friction from contact with the impeller cover. The damage described is typical due to rotation at the moment of impact.

1.5.2. Centrifugal impeller inner cover.
The cover had wear marks where the centrifugal impeller made contact while rotating.

1.5.3. Bearing No. 4.
It could spin freely and had no evidence of damage. The air seal had rotational damage and was found deformed.

1.5.4. Bearing No. 3.
This retaining nut had to be cut, as it had snapped into its design place, until the bearing could be removed. All bearing components did not show signs of breakage or abnormalities prior to impact. Components can rotate freely.

1.6. Reduction Gear Box (RGB).
About a quarter of the RGB total was present and found in pieces.

1.6.1. Bearing No. 1.
The bearing housing was intact; however, all rollers were missing. There was no evidence or signs of abnormalities prior to the accident.

1.6.2. Bearing No. 2.
The bearing housing was intact; however, all rollers were missing. There was no evidence or signs of abnormalities prior to the accident.

1.6.3. Gears
The input shaft gear teeth showed fractures caused by a mismatch along their axis, but no evidence of abnormalities prior to impact was observed. There were rotation marks along the input shaft. 1st and 2nd stage gear teeth showed impact damage. It was not possible to access the output shaft as it was slightly bent which makes it difficult to remove.

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1.6.4. Gearbox accessories.

The transmission gears of the gearbox accessories are bent and fractured due to impact. There was no evidence of pre-impact damage to any of the gear teeth of any of the accessory components. There was no evidence of pre-impact abnormalities in any of the available bearings.

1.7. Evaluation of controls and accessories.

The FMM was removed from the motor housing, the Flow Divider Valve (FDV) was located which showed signs of temperature damage and was not attached to the motor. The EEC showed signs of fire damage and the EEC housing was bent in multiple locations.

1.7.1. Electronic Engine Control (EEC).

N/P 1002904-2-104
S/N See 3

External condition and cleanliness.
The EEC's (EEC206-100[1]) were found in a dirty condition with signs of high temperature damage; the housings of both components were bent in multiple locations. In both components, loose debris inside could be heard when handling the unit. The experts of the engine manufacturer notified the investigators that they did not have the ability to open the component and therefore suggested that it should be sent with its manufacturer, the working group deciding, by mutual agreement, to send these components to the facilities of Collins Worldwide Electronics Repair Center, located in Windsor Locks, Connecticut, United States, to open them and obtain the non-volatile memories and verify if it is possible to obtain information.

1.7.1.a. Destructive inspection result.

On April 17, 2019, NTSB personnel, in coordination with the Investigator in Charge, witnessed the destructive tests carried out on EEC's at the Collins Worldwide Electronics Repair Center, Windsor Locks, Connecticut, United States, the results of these destructive tests were as follows:

Unit 1	Part number 1002904-2-104	Serial number See 3

External inspection
Both EEC206-100 were severely damaged by impact and subsequent presence of fire, Unit 1's housing was deformed.

Internal inspection
The electronic card was severely damaged by fire, many of the electronic components had detached from the card as a result of the fire and the rest of the internal card was burned and charred.

Unit 1:
Because the connector to the motor was present in the EEC, a complete disassembly of the unit was not possible, however, several of the components were detached from the motherboard by the heat of the fire during the accident, therefore it was possible to move the card far enough to reach the loose pieces and remove them. The memory chip containing the non-volatile data one of the loose pieces which were intact, thus it was cleaned for its identification and possible data recovery.

[1]The EEC206-100 is a single channel digital electronic control in conjunction with a Mechanical Fuel Control (MFC), monitors and adjusts the fuel flow to the engine.

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Non-volatile memory (NVM) data recovery and testing.
The tests were not possible due to the conditions of the units. An attempt was made to retrieve the NVM (Non-Volatile Memories) data from the memory chip through a data reading device, however the memory chip does not communicate with the data reading device. The memory chip was probably internally damaged by the heat produced by the heat of the accident. It was not possible to retrieve data from the NVM.

1.7.2. Inspection of the Flow Divider Valve (FDV).
The FDV showed signs of fire and was not connected to the engine so it was sent to the specialized workshop within the Pratt & Whitney Canada facility.

N/P: 8063-174
S/N See 3

External condition and cleanliness.
The heat shield was damaged and showed signs of overheating. There was white powder in the housing on the opposite side of the heat shield. The fuel manifolds were still attached to the FDV. One of the manifolds was removed to find out the condition of the "O" (o ring) seal, it had turned to dust. Testing was not possible.

Disassembly sequence and results.
The FDV was in shutdown mode, which is the expected behavior because the charging spring sends it to the closed position and without the fuel pressure the spring will close the valve. The green tank piston showed heat damage in the seal groove. One of the side walls was deformed and there was a crack in the radius that attached the side wall to the outside diameter of the groove. All the "O" seals were burned out. The internal valves moved freely. There were signs of overheating in most of the components. There was no abnormal wear on the contact surfaces.

1.7.3. Fuel Flow Module (FMM) inspection.
The FMM was removed and sent to the specialized workshop within the Pratt & Whitney Canada facility. The FMM technical data plate was not attached to the FMM body. Based on the maintenance records of the engine that was ordered by the Aeronautical Workshop of the Rotor Flight Services, S.A. de R.L. de C.V. (RES), the serial FMM See 3 was the one that was installed. The serial number was verified and compared with the original records, detecting that the serial number was See 3. The serial number coincides the one registered in the operator's and manufacturer's component control, thereby confirming that this component was installed since the manufacture of the engine.

N/P: 8063-1029
S/N: See 3

External condition and cleanliness.
The external surface was covered with soot and white powder. The teleflex cable was still connected to the power lever. The heat shield was bent preventing the determination of the position of the power lever so it was necessary to remove a section of the heat shield in order to visually access the power lever. The power lever was in the maximum position. Further disassembly of the teleflex cable showed that the fork of the power lever was bent on the side of the maximum stop screw, the lever was bent due to the impact.

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The input shaft of the pump was broken. Some sections of the case were missing, including the data plate. The fuel filter housing was broken. The power lever rotated effortlessly.

Security guards.
There were remnants of the security wires. Some wires were not present, it is assumed that they melted during the fire after the accident.

Disassembly sequence and results.
The fuel pump gears showed signs of overheating (bluish). The packages were dry. There were water droplets in the cavities of the FMM. The fuel pump bearings had a dull appearance. The impeller wheel was turning by hand. An aluminum notch was present in one of the drive gear teeth. The fuel filter was burned out. Debris was present in the fuel filter housing. The fuel filter housing was separated from the fuel pump housing, allowing contaminants to enter through the openings to the atmosphere. These contaminants were likely from the post-accident event.

The cover was removed and the interior of the FMM showed something like fuel varnish on most surfaces. All three "D" cam fuel filters melted. The servo piston of the CEE fuel valve, according to the fuel inlet position. The piston was pushed in the minimum stop. The fuel valve was not turning and was removed with difficulty. A more detailed examination of the fuel valve showed the presence of molten nylon in two clamping rings. The fuel valve lever set screw is damaged, preventing its removal. The fuel valve piston shaft was cut off to allow removal of the fuel valve. The nylon fuel valve filter was found melted and had leaked through the piston and liner windows. Most of the molten nylon entered the cavity between the housing bore and the fuel valve shaft. The buildup of molten nylon was localized and was creating a lateral load on the fuel valve shaft, which explains the difficulty in removing the fuel valve. The bearings rotated freely. Counterweights moved without restriction

The speed adjustment valve and the speed valve servo were not moving. Both valves were removed from the housing. Both valves worked once removed. Closer examination showed hole damage, roll, and cracks. All the other valves were free to move. There was no abnormal wear on the contact surfaces.

1.7.4. Data Collection Unit (DCU)[2] inspection.
On March 26, 2019, TSB personnel in coordination with the Investigator in Charge, witnessed the destructive tests carried out on the DCUs at the Safran Electronics & Defense Canada facilities, Peterborough. Canada, the results of these destructive tests were as follows:

External visual inspection indicates that both units were severely damaged by fire. The serial numbers were legible and the serial numbers were confirmed to be See 3 and See 3 he ID tag on DP09-6194 was missing, but the ID tag in See 3 was confirmed to be the part number See 3

[2]The DCU is the electronic device that stores information from the engine condition monitoring system, it is interconnected with the EEC through an electrical harness. This component provides information on the gas temperature (MGT) and engine torque at the output of the arrow (Q) to the EEC (Electronic Engine Control) for the evaluation of the differences in the measurement system, it also stores faults, exceedances and control system events detected by the EEC.

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S/N See 3 [redacted] component.
It has heat damage internally. The insulation melted from the wires; the gasket melted from the J1 connector. All electronic components came off the electronic board and peeled off the case, including the NVM chip. The NVM chip was recovered inside the housing and cleaned.

Data extraction was attempted using the Data 1/0 3980 reader:

When the memory component was placed in the reader and the action to extract the data was initiated, the reader sent an error message, "EMPTY SOCKET". This error indicates that there was no response from the NVM. Multiple attempts were made and the component connectors were lightly sanded to ensure proper physical contact was made between the reader and the component, but the same results were obtained. Thus, it is concluded that extreme heat exposure fatally damaged the component and as a result saved data was permanently lost from this drive.

2. Inspection result of the right engine.
The engine position number two, Pratt & Whitney Canada brand, model PW207C series See 3 [redacted], which according to the data provided by the RFS Workshop had the following updated times as of December 25, 2018, according to the same workshop.

Total time: 1,936.4 hours.
Time since last inspection: 28.1 hours on November 28, 2018.
Total cycles: 2,610 cycles.

2.1. External condition.
All external pipes and wires are deformed, cut or crushed due to impact. The gearbox section was still attached to the compression section.

2.1.1. Compressor inlet.
The compressor inlet housing broke into pieces, which make up about 2/3 of this section. The inlet was deformed and did not have the protective mesh. There were no signs of loss of the protective mesh before impact.

2.1.2. Diffuser.
There was minor deformation in the two diffuser tubes which is consistent with the deformation found in the gas generator housing, soot is present everywhere.

2.1.3. Gas generator housing.
It showed minor deformation in the bolting flange and the exhaust temperature lines were broken. The exhaust nozzles were crushed due to the impact and were no longer attached to the engine.

2.1.4. Turbine support housing.
Non-physically noticeable impact blows were noted, however there are other parts with considerable damage.

2.1.5. Gear reduction box.
It has deformation due to impact. There was a large amount of soot from the fire after the accident. The box was deformed and fractured into multiple pieces.

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2.2 Magnetic particle detector (Chip detectors) and filters.
The particle detector was not present in the engine, it fell off due to the impact. The oil filter was not present in the engine, it fell off due to the impact.

2.3 Turbine section.
2.3.1. Power turbine.
All blades were intact and present, with some leading-edge friction (with the stator) and the disc tips had friction with the cover. There was no apparent damage to the leading edge.

2.3.2. Power turbine shaft.
The power turbine shaft fractured in the forward section at bearing number 3. The surface of the fractures is at a 45-degree angle, which is a sign of overload. There are several friction marks where the shaft showed signs of rotation when making contact with the impeller and the CT (turbine compressor) disk.

2.3.3. Bearing No. 5.
This bearing rotated freely and there were some black marks which is typical on these engine models.

2.3.4. Power turbine cover.
It shows signs of friction along the panel along the entire circumference.

2.3.5. Power turbine stator.
The blades showed no signs of damage. The outer edge of the deck shows evidence of slight contact with the blade decks. The inner cover shows evidence of friction from contact with the CT blades on the decks.

2.3.6. Gas generator turbine compressor.
All blades were present and no damage was observed. The tips of the blades show signs of extensive friction. The lateral internal platform showed signs of rubbing with the stator of the power turbine.

2.3.7. Turbine compressor cover.
The turbine compressor showed signs of heavy contact friction and material transfer throughout its 360 degrees.

2.3.8. Turbine compressor stator.
It showed no signs of damage, however it did show some silver colored stains/deposits on the back of the paddles.

2.4. Combustion section.
2.4.1. Combustion chamber.
The combustion chamber darkened due to soot; however, there was no apparent damage.

2.5 Compressor section.
2.5.1. Centrifugal impeller.
Before disassembling, the impeller was rotated by hand force. There was damage to the leading edge, as well as material rolled in the opposite direction to the direction of rotation, typical characteristics from impact. The impeller blades exhibited friction along the exducer portion from contact with the impeller housing. The described damage is typical due to rotation at the time of impact.

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2.5.2. Centrifugal impeller inner cover.
The cover had wear marks from where the centrifugal impeller touched while rotating.

2.5.3. Bearing No. 4.
It could rotate freely and had no evidence of damage.

2.5.4. Bearing No. 3.
This ball bearing had to be cut off as it was wedged in its design location. The external part showed no signs of deterioration, but a discoloration due to the heat. The inner track showed no signs of disintegration, but did show some discoloration due to heat. The bearing balls showed no signs of detachment and could rotate freely.

2.6 Reduction gear box.
About a quarter of the RGB's diaphragm was recovered and was in pieces.

2.6.1. Bearing No. 1.
The housing was intact; however. the rollers were missing. There is no evidence or signs of abnormalities prior to the event.

2.6.2. Bearing No. 2.
The flange was fractured into four sections located on the mounting bolts. The bearing showed no evidence of breakout or pre-impact damage.

The gear teeth on the shaft showed a tear caused by a mismatch, but no evidence of pre-impact abnormalities was seen. The output shaft did not show evidence of pre-impact abnormalities; however, the output flange was bent.

2.6.3. Gears
The input shaft gear teeth showed a tear caused by a mismatch, but no evidence of pre-impact abnormalities was seen. The 1st and 2nd gear stages showed no signs of pre-impact abnormalities. The output shaft did not show evidence of pre-impact abnormalities; however, the output flange was bent.

2.6.4. Gearbox accessories.
Fuel flow module (FMM) drive/fuel pump and oil pump gears bent due to impact. There is no evidence of pre-impact damage to any of the gear teeth of any of the accessory units. There was no evidence of pre-impact abnormalities in any of the bearings.

2.7. Evaluation of controls and accessories.
2.7.1. Electronic Control Unit (EEC).

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S/N: **See 3** [redacted],

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External condition and cleanliness.
The unit was covered in dust. The four rubber bushings were missing from the mounting point. Connector contacts were missing. The housing was discolored due to exposure to high temperatures. When moving the unit, a sound coming from inside could be heard.

2.7.1.1 Result of destructive inspection.

Unit 2	Part number 1002904-2-104	Serial number 09120012

External inspection.
Both EEC206-100s were severely damaged by impact and subsequent fire.

Internal inspection.
The electronic card was severely damaged by fire, many of the electronic components had detached from the motherboard as a result of the fire, and the rest of the internal cards were burned and charred.

Unit 2.
The memory chip containing the non-volatile data was detached from the motherboard due to the heat of the fire during the accident, it was located inside the EEC case. The memory chip was cleaned for identification and possible data recovery. The memory chip pins were intact.

Non-volatile memory (NVM) data recovery and testing

Unit 2.
Testing was not possible in EEC due to unit conditions. An attempt was made to recover the NVM data from the memory chips through a data reader device, however the memory chip does not communicate with the data reader device. The memory chip was probably internally damaged by the heat produced by the fire from the accident. It was not possible to retrieve data from the MNV.

2.7.2. Flow Divider Valve (FDV).
The FDV showed signs of fire and was no longer connected to the engine so it was sent to the specialized workshop within the Pratt & Whitney Canada facility.

N/P: 8063-174
S/N: **See 3** [redacted],

External condition and cleanliness.
The fuel manifolds were still attached to the FDV. One of the flange mounting ports was damaged. One of the manifolds was removed to check the condition of O seal. The O Seal had turned to dust. Operational testing was not possible.

Detailed teardown sequence and results.
The FDV was in shutdown mode. The transfer valve sleeve could not be removed. The housing was outside preventing the shirt from being removed. The flange of the eco-shirt was distorted. Steel components discolored due to exposure to heat. The pistons were free to move inside the jackets. There was no abnormal wear on the contact surfaces.

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2.7.3. Fuel Management Module

The FMM was disassembled from the engine and the fuel lines were removed and there was some fuel remaining. It was sent to the specialist workshop within the Pratt & Whitney Canada facilities. The technical data plate was missing. Based on the maintenance records the S/N See 3 was verified against the original records. The serial number was WSF03066 and this matched the serial number recorded in the operator and manufacturer's component control, confirming that this component was factory installed on the engine.

P/N: 8063-1029
S/N: -See 3

External condition and cleanliness.

The outer surface was covered with dirt. The Teleflex cable was still connected to the power lever, but was loose in the housing. The position of the power lever was at the maximum stop. The lever grip was bent on the side of the maximum stop screw, suggesting that the lever was bent upon impact. Some sections of the case were missing. The fuel pump mounting flange was damaged at three of the four attachment points. The input shaft was broken. The fuel filter case was broken. The power lever was easily rotated by grasping the lever with pliers.

Security guards.

There were remnants of the security wires. Some seals were missing, presumably melted during the post-event fire.

Disassembly sequence and results.

The fuel filter was clean and no contaminants were found between the pleats. Debris was present in the fuel filter case. The fuel filter case was separated from the fuel pump case, allowing contaminants to enter through the openings to the atmosphere. These contaminants that lodged inside the fuel filter probably got inside from impact with the ground. There was slight corrosion on the gears and bushings. The contaminants came from the subsequent impact, as there was an opening to the atmosphere due to the separation of the fuel filter case.

The cover was removed and the inside of the FMM was contaminated due to the opening in a section of the main body that was torn out. All three "D" cam fuel filters were clean. The EEC fuel valve servo piston, as received position, was measured by extruding down 4 lines from the face of the case. The piston was pushed against the maximum stop and the piston was measured to be extruding with 4 lines. The bearings rotated freely. The counterweights were moving without restriction. All valves were operational. There was no abnormal wear on the mating surfaces.

All the internal components described below which are part of the MMF show evidence of over temperature, with no free movement due to the over-temperature to which they were exposed:

- Minimum pressurizing and shut off valve
- Over speed
- By pass valve
- Min Flow
- 3DCAM

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- Bail head
- Pressurizing valve
- Servo valve
- PC regulator
- Fuel valve

The fuel filter was found to be carbonized due to the external overtemperature to which the MMF was subjected at the accident site.

2.7.4. Data Collection Unit (DCU).

External visual inspection showed heat damage, but not as severe as S/N See 3. The case was blackened, the MNV chip was not welded to the board, but was embedded inside the case. The MNV chip was removed and cleaned.

S/N DP09-6502 Component.

It shows heat damage internally. When the memory chip was placed in the reader and the action to extract the data was started, the reader sent the error message, "CONTINUITY TEST FAILED". This error message indicates that there was no response from the MNV chip. Multiple attempts were made and the component contacts were lightly sanded to ensure proper physical contact between the reader and the MNV chip, but the same results were obtained. It is therefore concluded that extreme heat exposure fatally damaged the non-volatile memory chip and consequently the data in this unit.

3. Comparison between engines.

When looking at the two engine components side by side, it can be seen that they have the same damage. Both engines had all of the power turbine blades in place, although there was rubbing of the power turbine blade tips with the power turbine discs with the power turbine stator. Both power turbine shafts exhibited 45-degree angle fractures just behind bearing number 3. Both engines experienced high rotational samples due to contact with the drive and the compression turbine disc assembly, as well as along the power turbine shafts prior to the fracture behind bearing number three.

Both engines had all compression turbine blades in place with no fractures and there was no evidence of pre-impact damage that would have prevented normal operation. Both engines showed rubbing on the tips of the compression turbine blades due to the accident.

The two centrifugal drives of the engines had their leading-edge blades bent in the opposite direction of rotation, which is indicative of rotation on impact. The finding that the two air intakes were compressed but their meshes were not damaged further indicates that the damage occurred on impact, after air intakes were compressed allowing debris to enter and strike the leading edges of the impellers.

4. Conclusions.

Exhibit B is based on what was observed during the disassembly of the engines during the week of March 4-8, 2019. Based on the findings it is concluded that the engines present damage characteristic of being operational and producing power at the time of impact against the ground.

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Although the power level could not be determined, similar damage to both engines indicates that the two engines were operating at similar power at the time of impact. The non-volatile memory components (EEC's, DCU's) that could confirm the above, were damaged by the fire, so they could not provide data.

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Exhibit C

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1. Inspection to the Data Acquisition Unit (DAU).

The electronic component called Data Acquisition Unit, DAU, NP 109-0900-76-6AO1 S/N See 3 was located at the site of the accident. By decision of the group of investigators and the manufacturer's experts, it was decided that this component would be moved to the Logic S.p.A. facilities in Cassina De'Pecci, Milan, Italy, in order to extract the information.

Visual inspection

Initial visual inspection revealed extensive fire damage to the unit. The case was found to be badly distorted with the side cover partially out of design location. The front of the case was severely damaged; the battery was no longer in place leaving a bore from which the internal parts were visible.

It was assessed that upon moving the DAU, some of its internal components were dislodged along with a large amount of black powder. These components could not be identified as they all exhibited heat damage and no related part number information could be collected.

Internal inspection

The case was opened to assess the internal condition of the component by removing the side cover for which it was necessary to cut the case bracket still attached to the rear connectors.

Subsequently, the side cover was removed and the internal electronic boards were exposed. All boards showed mechanical deformations and severe fire damage. The two boards where the NVM (Non-Volatile Memory) chips are installed were removed for further inspection. The boards on which the NVM chips are installed were cleaned while the rest of the cards that do not store information were removed from inside the DAU case. The cleaning of the boards highlighted that all the electronic components of the boards were detached as a result of heat exposure.

Upon inspection inside the DAU case, a number of chips with different shapes and dimensions were observed, all of them showing extensive heat damage, however, it was possible, by comparing the shape and number of pins to identify two non-volatile memory chips that were installed on the two boards.

Due to the temperature damage to which they were exposed, it was not possible to clearly identify the part number of these chips or to evaluate the original position on the NVM cards.

The two chips were inspected using an optical microscope to evaluate their condition. The first chip inspected was identified as "CHIP 1" and was completely covered with soot. On both the top and bottom sides, a series of cracks were identified along the perimeter of the chip. All of the connection pins were still present; only two of them showed small deformations, but they were still in their design position.

CHIP 2" also showed the same evidence as "CHIP 1". Remnants were identified on two of the pins that probably came from other components.

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Data recovery.

Despite the severe damage observed, it was agreed that a data recovery attempt should be made on both chips. Both chips were connected, however, the reader sent a memory error message so data recovery was not possible.

1.1.Conclusions from the DAU Inspection.

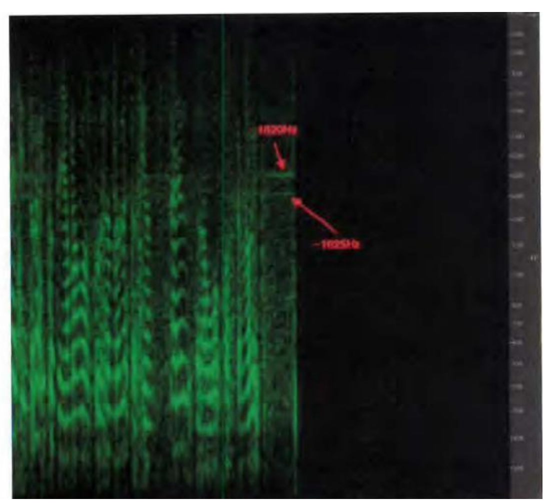
The inspection managed to identify 2 of 16 non-volatile memory chips. The two chips recovered showed extensive damage from being exposed to heat and fire compromising their functionality. Therefore, no data was recovered.

2. Results of the inspection of audio of communications.

At the meeting held from April 01 to 12, 2019 at the Leonardo Helicopters facilities, located in Cascina Costa, Milan, Italy, the Investigator in charge shared with the group of experts the audio of the communications established between the XA-BON aircraft and the Puebla Control Tower, so he requested the Manufacturer to perform a spectrum analysis of the available audio to identify in the frequencies, relevant sounds to aid the investigation.

The investigator in charge handed over an audio file that includes all communications established by the XA-BON crew with the Puebla Control Tower, as well as other radio communications from other aircraft. The file has a duration of 00:14:58.368 minutes, which was provided by SENEAM through the Puebla Control Tower. According to the manufacturer's report, the quality of the audio file content is very poor, however, they managed to identify, with the help of software in the frequency of the XA-BON audio file, the near 1'820 Hz rotation frequency of the coupling between the Gleason pinion and the gear inside the Main Gear Box case and possibly a second harmonic that is compatible with that of the planetary gear (Planet Gear) 7'625 Hz, both with reference to the rotation speed at 700%. Due to the low quality of the audio, they were unable to identify other frequencies in the XA-BON audio file.

2.a. Sample audio



2.b . The audio spectrum shows the two frequencies

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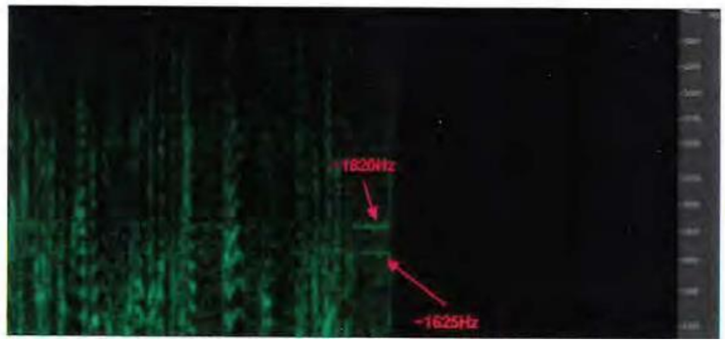
Leonardo Helicopters' specialist area also performed the analysis to the last transmission from the helicopter, at minute 00:14:486, in which there is no voice or evidence of helicopter identification, this transmission lasts approximately 200 msec. This communication was primarily affected by noise throughout the transmission, however, the software performing the spectrum analysis was able to identify a frequency around 1'820 Hz that appeared to fluctuate slightly in the range between 1'820 Hz and 1'775 Hz. This frequency of 1'775 Hz is compatible with a rotational speed of approximately 98%, this being the last transmission in the audio file.

2.c. Audio from min 00:14:486



2.d. Fluctuation in main rotor rotational speed

2.1. Conclusions from the audio of communications.

Considering the audio evidence of the communications established between the XA-BON and Puebla Tower Control, it is possible to determine that the XA-BON did not show any unusual frequency behavior during the communications established with the Air Traffic Services.

The last part of the audio located at 00:14:486 min of the audio file highlights a possible fluctuating frequency around 1'820Hz, however, from the available evidence it cannot be determined at what time of the flight this fluctuation occurs and correlate it with the time of loss of control of the helicopter.

This fluctuation could also be due to a change in helicopter attitude or wind direction.

3. Inspection of the Master Warning (MW) and Master Caution (MC) panel lights.

The investigators at the accident site located among the wreckage of the helicopter an instrument panel indicator called Master Warning[1] (P/N 109-0729-43-3) and one of Master Caution (P/N 109-0729-43-1), so at the meeting held from April 01 to 12, 2019 at the facilities of Leonardo Helicopters, the Investigator in charge requested Leonardo Helicopters' experts to perform a destructive test to the bulbs installed in each indicator and determine if these bulbs were lit at the time of the accident, whereby the manufacturer's experts determined the following:

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[1] Each IVIW and MC indicator is located on one side on the left side and one on the right side of the instrument panel. Each indicator includes a push-button switch to relay the indicator and for safety reasons, each indicator contains four independent bulbs per indicator.

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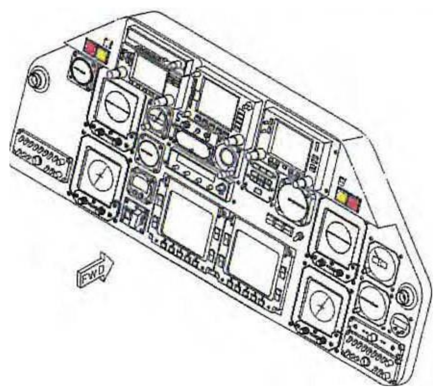
3.a. Master Caution with its bulbs in its interior

3.b. Master Warning with its bulbs in its interior

The Data Acquisition Unit (DAU) processes all the signals received by the sensors installed in the helicopter and activates the MW and/or MC indicators. When a warning signal is displayed, the two MW indicators flash at a flash rate of 4 ±1 Hz, and disable their operation when the warning reset discrete signal is issued through the activation of the MW switch. If there is a fault in the flashing circuit, then there will be a steady-on condition for the MW. This same process occurs for the caution signals on the MC. Relaying the MW and/or MC can be done through the master reset push-butt on button located on the pilot's collective control stick lever or on the button located on the helicopter control panel, at the same time, in case of equipment/system malfunction, it is displayed through the red warning messages or yellow caution messages indicator.



3.c. Location of Master Caution & Warning Lights on instrument panel

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Bulb.

It is a small incandescent glass bulb with an inert gas inside to prevent oxidation of the filament, the filament structure is made of tungsten and a base. In Figure 3.a., a typical lamp, type 327, is shown. Depending on the bulb, the filament may have various geometries and may be supported only at its ends by contact posts or have additional supports at intermediate points from the support posts (see Figure 3.g.). In the units in question, 28-volt incandescent bulbs, type 327 T-1-3/4 with poles in between, are used; this type uses the C-2F configuration, where the "C" designation indicates that a coiled filament is used, while "2F" is the designation for the support structure.

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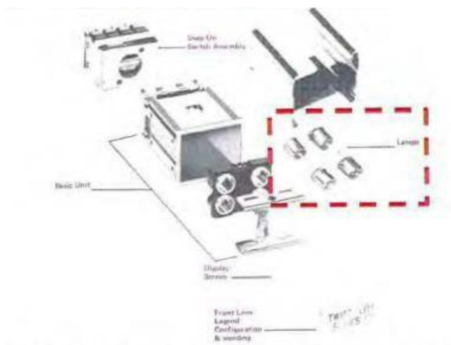

3.d. Location of bulbs inside the MC and MW lights

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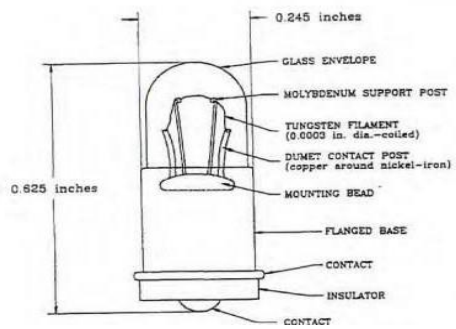
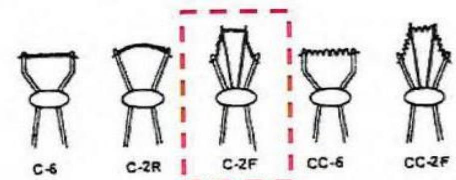


3.e. Characteristics of a type 327 bulb



3.f. Bulbos 327, T-1-3/4 con postes en medio

3.g. Filament type

Initial observation.
An initial visual inspection highlighted significant mechanical damage to the MC and MW gauges; however, there was no fire damage. The cases of both Master Lights were intact, slightly crushed due to impact. The front of the MC light is not damaged was in place and the glass is not broken. The front of the MW lights was damaged and was not in place, although it should be noted that the glass is not broken.

Disassembly.
The MC case was removed without major problems while the MW case had to be cut to remove the internal unit without risk of damage, all the bulbs were removed and showed no damage. For each MW and MW indicator, the 4 bulbs were identified with the letters "A", "B", "C" and "D" following the inscriptions on the rear side of the basic unit from which they were extracted.

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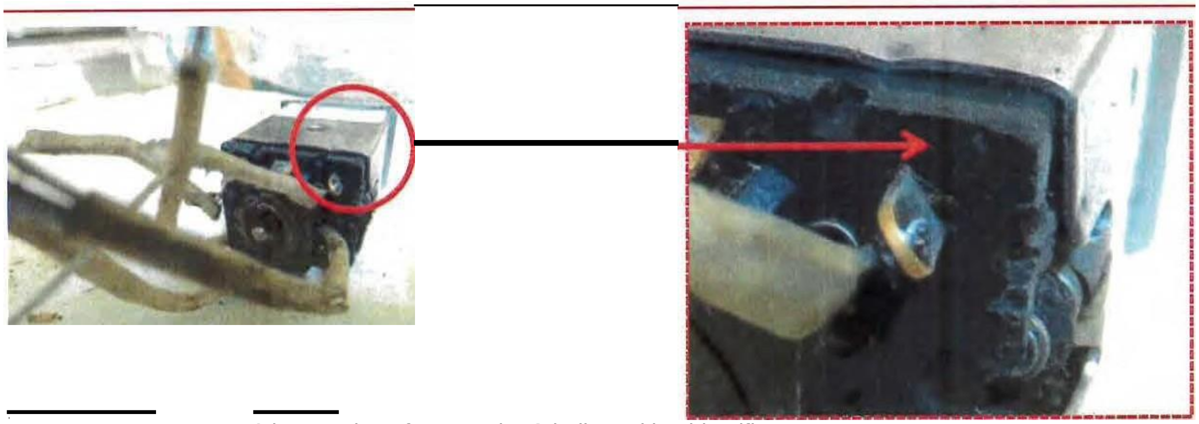


3.h. Location of MW and MC bulb position identifiers

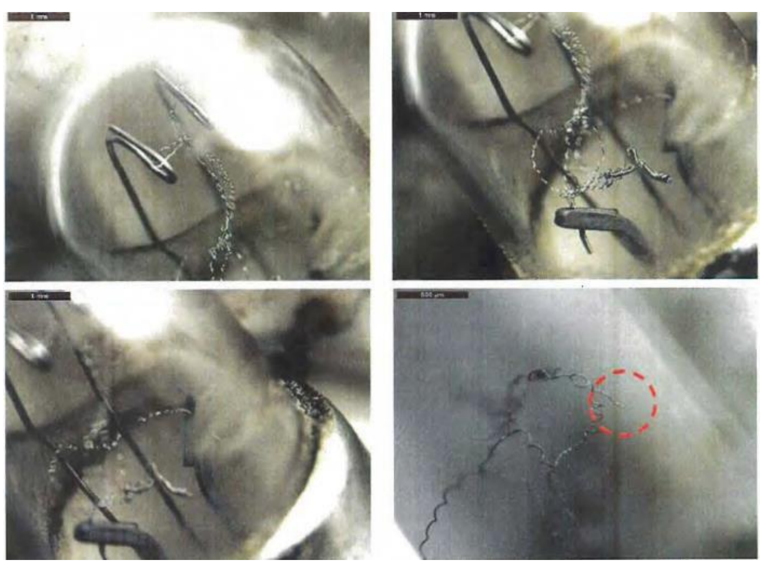
Electrical conductivity test.

An electrical continuity test was performed on the eight bulbs, the results are presented in the following table.

	A	B	C	D
Master caution bulb	Positive	Negative	Positive	Positive
Master warning bulb	Positive	Positive	Positive	Positive

Internal inspection.

Images taken stereo-microscopically show deformation of the bulb filaments. All bulbs were found to be undamaged. Only MC bulb B failed the electrical continuity test and shows a fractured filament.



3.1. MC bulb B, glass cover intact, fractured filament (red circle) with high deformation.

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Nondestructive inspection of MW and MC indicators, in the NTSB.

After the meeting held from April 1 to 12, 2019 at Leonardo Helicopters facilities, the Investigator in charge (IAC) went on April 15, 2019, together with the representative of the helicopter manufacturer in Mexico, to the hangar where the wreckage of the helicopter is kept, managing to recover from the wreckage the two remaining Master Warning and Master Caution indicators, so the IAC decided together with the representative of the NTSB to send these components and the right hydraulic pump for the corresponding destructive tests.

On July 26, 2019, the nondestructive inspection performed by NTSB experts on the MW and MC gauges was carried out, concluding the same as Leonard or Helicopters' experts that the lights were on at the time of the accident.

3.j. MW bulb B, the glass cover is intact, as well as the elongated filament.

3.k. MC bulb B, the glass cover is intact, as well as the elongated filament.

3.1 Conclusions on the MC and MW bulbs.

Investigation indicates that the lights were ON at the time of impact. All bulbs, observed under the stereo microscope, show the filaments with high deformation consisting of snaking, tangling and stretching, typical of a hot ductile filament after a severe impact (high gravities and short duration). In particular, filament tangling is a strong indication that the bulbs were ON, this type of deformation has never been observed in cold filaments (light off) subjected to an acceleration of 2.5OO g.

All filaments are intact, except for MC bulb B, which shows a fracture. The fracture surface observed in the Scanning Electron Microscopy (SEM) shows a smooth and rounded appearance, indicating that the filament was hot at the time of impact. Although the investigation of the MC and MW indicator bulbs indicates that all 8 lamps were ON at the time of impact, it is important to consider the possibility that the initial impact may have caused electrical damage that changed the state of the bulbs, showing a false caution/warning indication that did not exist prior to impact.

Finally, the Master Warning and Master Caution lights could also have been activated by conditions such as ROTOR HIGH, ROTOR LOW, transmission oil pressure (XMSN OIL PRES), etc., due to possible extreme attitudes of the helicopter in the moments prior to impact.

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Exhibit D

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1. Results of the inspection of the wreckage of the basic body.

After completion of the field investigation and assembly of the helicopter, the investigators and experts determined to send the wreckage of the components involved in the control of the helicopter to the Leonardo Helicopters manufacturer's facility located in Cascina Costa, Milan, Italy, for a more detailed inspection of the components.

These activities were scheduled to be carried out from April 07 to 12, 2019, the work consisted of performing an initial visual inspection and subsequently based on the findings, the type of inspection to which the component would be subjected, either destructive or non-destructive, would be determined. Based on this scope, together with the representatives of the helicopter manufacturer, a factual report of the inspection of the components was prepared, signed by all the Accredited Representatives of the States entitled to be present at the investigation, which concludes as follows:

1.1. Engine Control Lever (ECL).

During the field investigation activities these components were found with the levers in the MAX[1] (maximum) position, the assembly showed major damage. The manufacturer (TEMA Avio) of this component participated in the inspection and performed the reconstruction through a destructive inspection to both ECL levers finding the following:

Detailed inspection.

It was observed that the ECL assembly was covered by dirt and other contaminants, several parts of the ECL assembly were completely detached from the ECL. These parts were coming from the top of the assembly where the mechanism is installed.

The underside of the ECL (facing the interior of the cabin) showed damage to both levers which were fractured near the fairing, centimeters above the location of the ignition buttons. All connectors and cables showed severe heat damage and most of them were affected by the impact.

Both controls appeared to be stuck in the MAX position. The lever for engine 1 was able to move freely throughout the travel stroke, while the lever for engine 2 was stuck in position due to the presence of external material (dirt and rocks). After removing these fragments, the lever could move freely.

One of the two electric engines (Engine 2) was found completely separated from the ECL assembly and the endless worm was observed to be fractured near its root with obvious bending deformation along its length; also, the pin of the mechanism was fractured and the rest of the pins were found inside the bracket. The electric motor of engine 1 was found still attached to the ECL assembly, even when it was affected by impact damage. Its worm gear was also found to have a fracture surface almost identical to that of engine 2. The support mechanism was also found to be fractured.

The major damage to the ECL assembly did not allow any electrical testing to be performed. The damage observed is consistent with a high energy impact, most likely the initial impact was in an upside-down manner with a tendency towards the side of engine 2. Both levers were found in the MAX position, but both levers could also move freely due to the fracture.

[1] The MAX position indicates maximum fuel flow at FM M and corresponds to MANUAL mode operation when selected.

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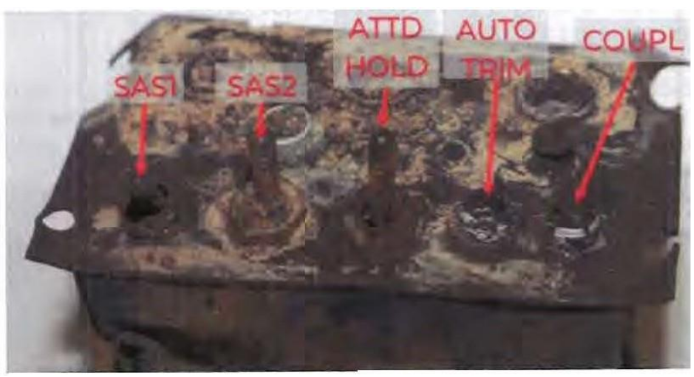
Both bolts were fractured near the root of the mechanism and the brackets connecting the bolt to the levers were found in a position consistent with a lever in the FLIGHT[2] (FLT) position. The levers in the MAX position are consistent with the helicopter impacting the ground in inverted form, the levers were moved to the maximum power position which is consistent with the reading that was obtained in the field investigation.

1.2. Helipilot control panel assy.

Of the five switches on the control panel, three switches remained on the control panel and two were not present. The three switches present are "SAS1 ", "SAS2", and "ATTD Hold". The SAS1 was found to be in the OFF position. The "SAS2" and "ATTD Hold" were in the ON position. The "Auto Trim" and "Coupl/Decoupl" switches were not present. The "SAS1" switch could be pushed to the "ON" position but would not remain in that position as it automatically returned to the OFF position, this happens when no power is applied to the helicopter and this behavior is expected from this switch.

It is worth mentioning that the SAS1, SAS2 and ATT HOLD switches are magnetically retained, and the default positions when no 28 VDC power is applied to the panel are:

SAS1: OFF
SAS2: OFF
ATT HOLD: ON



12.a. Helipilot Control Panel assembly with found configuration.

1.3. Mast vibration absorber (MVA)[3].

During the field investigation at the accident site, the investigators and the manufacturer's experts noticed that the "MVA" mass or disk was not physically in its design location, so they were looking for this component during the time the accident site was guarded, the investigator in charge coordinated the search for the component with army personnel, police, investigators, however, there was no success. Even though this component was not physically present, the main rotor was sent to be the main component to be evaluated with the support of the manufacturer.

2 In the "FLIGHT" position, the Fuel Management Module (FMM) is in the neutral position, engine operation in "AUTO" mode is when engine starting is available and each Engine Control Unit (ECU) independently commands fuel flow to maintain a constant helicopter main rotor speed at 100% RPM or 102% RPM, whichever is selected.

3 The MVA is a dynamic system installed on the main rotor hub, which rotates with it and has the purpose of reducing the vibratory loads on the components that are transferred to the helicopter fuselage. Its basic operating principle is that of vibration damping, it is a dynamic system with a vibrating mass supported by an elastic element that has low damping and tuned in resonance with the frequency of the disturbance to be reduced. In this way, the device can reduce the vibrations of the structure where it is connected by absorbing part of the energy generated by the vibrating source.

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The first step in the inspection was the re-submission of the MVA cover, which had a bright yellow coloration on the inner surface consistent with the factory primer coating, and also showed bright silver colored scuff marks (aluminum metal under the primer application). There are dark colored marks around the contact marks (see image 1.3.a.). The cover was deformed upwards (see image 1.3.b).

During the disassembly of the deck, evidence of improper pre-torque installation on the deck could be seen because when the swashplate is installed without removing the MVA kit, the clearance between the rod head and the deck is greatly reduced causing the friction found inside the deck. Modular pattern[4] of friction is related to oscillation.

The above consideration leads to the hypothesis that the procedure for the installation of the swashplate, which is contemplated in the maintenance manual, may have been carried out incorrectly due to the findings observed because the MVA was not completely removed, although the torque was verified after 5-10 hours, as stated in the manufacturer's manual according to the maintenance records dated August 03, 2018, according to "sticker" recorded in folio 0839 of the flight log.

Lack of adherence to the swashplate removal procedure leads to a reduction of the clearance between the rod head and the cover, which causes wear and probably reduced vibration absorption of the MVA.

The fastening screw gores in the cover were labeled. The order of the numbers went from 1 to 8, with 1 starting with the screw gore aligned with the impact damage on the cover. It was analyzed under the optical microscope and the fracture surfaces in the fastening screw gores of the cover show no evidence of fatigue fracture.

1.3.a Internal surface of the cover

1.3.b. The cover is deformed upwards

Scuff marks were observed on the bar consistent with contact of the bar with the retaining nut. The marks were aligned with the impact area of the cover. The MVA case contained an arc-shaped mark on its interior consistent with the impact area of the MVA. The case also contained a crack near the scuff mark.

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[4] The modular friction pattern is related to the collision between the bar and the casing as shown in image 1.3.a.

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The friction found inside the cover is the result of the reduced space between the bar head and the cover.

The design clearance was probably reduced by an installation procedure that was not in accordance with the maintenance manual, which clearly indicates the complete removal of the MVA kit prior to the removal of the swashplate and its torque check after 5/10 hours of flight.

1.4. Main rotor controls.

1.4.1. Main rotor hub.

a. The main rotor hub remained attached to the main rotor shaft.

b. The "red" and "yellow" main rotor blade grips of the main rotor remained attached to the hub through their elastomeric bearings.

c. The interior portion of the grip of the main rotor "white" blade remained attached to the hub through its swashplate, but was displaced in a manner consistent with the spin with which it impacted against the ground. The outer part of the grip separated from its inner part, but was recovered from the wreckage.

d. The grip of the "blue" main rotor blade was separated from the hub, most of the elastomeric bearing remained attached to the grip with the remaining portion of the elastomeric bearing attached to the hub along with its flap stop.

e. “Red” main rotor blade.
The pitch control link upper rod end bearing remained attached to the pitch horn. The upper rod end threads exhibited slight deformation in the direction opposite to normal rotor rotation. The pitch change link rod (PCL rod) remained attached to the upper rod end bearing. The pitch change link rod was in one piece and showed no bending deformation or fractures. The lower rod end threads were bent in the direction of normal rotor rotation. The lower rod end bearing remained attached to the rotating section of the rotating swashplate.

The damper remained attached to the hub through its rod end bearing. The blade-side rod end bearing was removed from the damper and remained attached to the blade-side damper. A portion of the threaded damper sleeve remained on the thread of the blade-side damper rod end bearing.

f. “White” main rotor blade.
The PCL upper rod end bearing remained attached to the "pitch change horn (PCL)" but the threads were fractured and exhibited slight deformation in the normal direction of rotor rotation. The PCL (Pitch Change Link) bar was detached, but was found whole in the wreckage. The PCL bar showed no evidence of deformation or fractures. The remaining bar end threads on the link were bent in the direction opposite to normal rotation. The lower end bearing remained attached to the rotating swashplate and was fractured at its threads.

The drag damper remained attached to the hub through its end bearing. The blade-side rod end bearing was removed from the shock absorber and remained attached to the blade-side shock absorber. A portion of the shock absorber threaded sleeve remained on the upper end bearing of the blade-side shock absorber.

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g. "Yellow" main rotor blade.

The upper end bearing of the pitch change link remained attached to the "pitch change horn" but fractured at its threads and exhibited slight deformation in the normal direction of rotor rotation. The PCL bar was detached and showed no evidence of deformation or fracture. The PCL bar remained attached to the lower end bearing and the lower end bearing remained attached to the rotating swashplate.

The drag damper remained attached to the hub. The blade-side terminal bearing was removed from the shock absorber and remained attached to the blade-side drag damper. A portion of the drag damper threaded sleeve remained on the thread of the blade-side drag damper terminal bearing.

h. "Blue" main rotor blade.

The upper end bearing of the pitch change link remained attached to the pitch change horn. The upper end threads showed no bending deformation. The PCL bar remained attached to the upper end bearing. The PCL bar was whole and exhibited no evidence of deformation or fractures. The lower end bearing remained attached to the rotating swashplate, but separated from the PCL bar. The lower terminal threads were bent in the direction of normal rotor rotation.

The drag damper remained attached to the blade-side damper. The hub-side drag damper bearing remained connected to the drag damper and contained a remnant portion of the hub side, reflecting the fracture observed in the hub.

i. The main rotor blades show fractures due to overload, as well as their respective grips and elastomeric bearings.

1.7.4.a. Damage to all four main rotor blades

1.4.2. Rotating scissor.

The Rotating scissor upper link remained attached to the swashplate hub. The upper link was removed from its design position. The swashplate hub exhibit bolt and the upper link were bent so it was necessary to use a sledgehammer to remove the bolt. The upper link exhibited very slight torsional deformation and the installation orientation labels were not observed however it displayed the following information:

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A0126 ASSY (printed engraving)
PN109-8110-16-1 (printed engraving)
REV E SN 604 (printed engraving)
109-0110-17-3-F

1.4.2.a. Upper half of rotary scissors after disassembly

1.4.2.b. Rotating scissors before disassembly

The lower link of the rotating scissors was found in two pieces, one piece remained attached to the upper link of the rotating scissors (through the fixing screws) and the second piece remained attached to the rotating swashplate. The lower link could not be removed because it was deformed due to the impact against the ground. The fractures observed in the lower link pieces are consistent with a stress fracture. After removal of the rotating scissors, the swashplate assembly could be moved with the force of one hand in the lateral plane (forward, forward, right and left) without evidence of binding. The rotating swashplate could also be rotated manually in both forward and reverse directions. The fixed scissor link remained attached to both the fixed swashplate and the upper case of the main transmission.

1.4.3. Swashplate removal and disassembly.

The mast nut and upper cone were removed, no abnormal damage was observed on both parts. During the removal of the rotating scissor flange bolt, two of the bolts were found to be de-torqued, the other six bolts had torque present. The main rotor hub was removed from the main rotor shaft hub showing the lower split cone, the latter had no abnormal damage. The fixed scissor link remained attached to the fixed (non-rotating) swashplate, the fixed scissor was removed and the swashplate assembly including the swashplate support was removed from the main rotor shaft.

The main rotor shaft was free of cracks and the shaft could be rotated with hand force. The double bearing retainer of the swashplate was present, this bearing retainer was removed and subsequently the rotating swashplate containing the double bearing was removed.

The anti-rotation blocks of the uniball bearing were present and showed no abnormal damage. The double ball bearing was removed from the rotating swashplate. The cut on the inside diameter of the rotating scissor link bolt was filled with grease so that after removal of the grease, the bolt head was visible and showed no evidence of rotation as the bolt was deformed in the direction of normal rotor rotation.

Parts recovered from the labeled package of the mixer unit showed evidence of overload fractures and thermal damage. Additional parts from the flight control system cranks showed overload fractures. The terminals showed no evidence of a disconnection.

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1.4.4. Main rotor servo-actuators.

The left and right main rotor servo-actuators remained attached to the fixed swashplate. The upper end of the front, main rotor servo-actuator was connected to the fixed swashplate, but was fractured at its threads. The threads of the upper terminal exhibited bending deformation on the inside (towards the main rotor rotation shaft). The three uprights of the servo-actuators were fractured, the three input rods remained connected to the servo-actuator input links, but the input rod tubes were fractured and separated from their terminals.

The left and right servo-actuator terminals were attached to the pistons and showed bending deformation, the front servo-actuator body and feed link showed significant impact deformation. The servo was removed from the end bearing which remained attached to the fixed swashplate.

According to the maintenance records, the servos had the following times:

a. Front servo (Blue), P/N 109-0110-42-136, S/N 8313.
- The servo was installed on July 01, 2017 (total component time 1,603.47 hours).
- Support assembly, P/N 28007GR90, S/N 9262, was installed in as-new condition when the helicopter had 1,813.74 total hours; the serial number was visually confirmed at the accident site.

b. Left servo (Red). P/N 109 - 0110 -42- 134, S/N 6229.
- The servo was installed on July 03, 2017 (total component time 1,604.78 hours).
- Support assembly, P/N 28007GR90, S/N 8769, was installed when the helicopter had 1225.0 total hours and 1,047.5 total cycles, the serial number was visually confirmed at the accident site.

c. Right servo (Yellow), P/N 109 - 0110-42 -135, S/N 6257.
- The servo was installed on January 24, 2018 (total helicopter time 1,799.9, total component time 796.5 hours).
- Support assembly, P/N 29007GR90, S/N 9247, was installed when the helicopter had 1799.9 hours, the serial number was visually confirmed at the accident site.

The three servo-actuators of the main rotor were removed from the upper case and the fixed swashplate for further evaluation. At the meeting it was determined that a CT scan of the three servo-actuators would be performed and based on those findings it was determined that the disassembly of these components would be performed in Italy and supervised by the Accredited Manufacturer's Representative (ANSV).

1.4.5. Inspection to the main rotor servo-actuators (MRA).

On May 17, 2019, the results of the non-destructive inspection of the three servo-actuators of the main rotor were obtained, this activity was carried out by Leonardo Helicopters experts, under the supervision of the Accredited Representative (ANSV) and in coordination with the Investigator in Charge.

A GE phoenix vltomelx m® system scanner was used to perform the nondestructive tests, which has the following features:

- 290kV/200µA on microfocus X-ray tube
- 16MP detector (with 100µm pixel size)
- 2x2 pixel binning
- 2000 step/rev motor angular resolution
- Average of 3 captures far each step
- Final voxel resolution: 80-100µm (avg.)

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Blue MRA. Yellow MRA. Red MRA.

1.4.5.a. The three main rotor servo-actuators mounted on the scanner

This allowed the condition of the coil and relief valves to be documented prior to disassembly. The images were processed and analyzed with the VGStudioMax program.

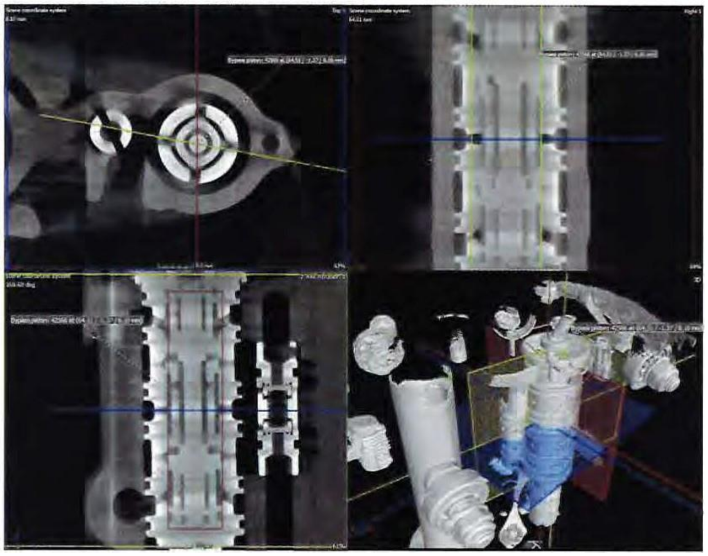
For practical reasons and to improve the resolution of the images, the scan was divided into an upper half (system# 2) and a lower half (system# 1) of the three main rotor servo-actuators resulting in a total of 6 3D images.

The inspection focused on the volume containing the coil and pressure relief valves. Part of the main piston chambers were also captured due to their geometry.

The 2 bypass microswitches and extensions were partially scanned, as they are extremely damaged and are not part of the servo-actuator control mechanism.

1.4.5.1. Blue Main rotor servo-actuator

- It has a part number 109- 0110-42-136 and serial number 8313.
- It has 2,389 total hours and 575 last major repairs.
- This MRA is installed at the front of the main gearbox.
- It shows extensive damage caused by impact against the ground, which caused the 4 connecting gores between the upper and lower halves, bending of the piston and significant torsional deformation of the feedback cam.
- The aluminum outer body was found to be fractured in several areas.
- The two pins connecting the cam inlet to the spool valve were also found displaced or fractured in the weakest section of the MRA.
- The terminal assembly and main gearbox upright adapter also failed due to overstressing.
- Both over-step micro-switch cases were displaced and badly deformed, but were still connected to the main body.
- The piston of the over-pass valve was fractured near the end of the bore.
- The control link was found connected to the bore through the pin.
- The position of the spool valve in the sleeve is not consistent with the upper one. This may be due to the failure of the connection between the upper and lower bodies upon impact.



1.4.5.1.a. View of the 3D images of the lower part of the blue MRA

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- The rest of the over-pass valve piston is intact, up to the connection with the extension.
- The servo-actuator piston is intact.
- The sleeve is intact.
- The pressure relief valve is intact.
- The extension was completely disconnected from the over-pass valve piston, as the microswitch case was crushed by impact forces against the ground.
- The over-pass valve piston showed plastic deformation outside the sleeve.
- The pin is disconnected from the bore.
- The servo-actuator and over-pass valve piston were removed from the sleeve, due to the impact the first O-seal groove was exposed.
- The rest of the over-pass valve piston was intact, up to the connection with the extension.
- The servo-actuator piston was intact.
- The sleeve was intact.
- The pressure relief valve was intact.
- The extension was completely disconnected from the over-pass valve piston, as the microswitch case was crushed by impact forces against the ground.

1.4.5.2. Yellow Main rotor servo-actuator.

- It has a part number 109-011-42-135 and serial number 6257.
- It has 1,175.3 total hours and 378.8 hours from its last major repair.
- This MRA was installed on the right side of the main gearbox.
- It has extensive ground impact damage, but significantly less than the blue MRA.
- The two pins connecting to the input cam were found in their design location.
- The terminal assembly was bent, but still bolted to the main piston. The main gearbox strut adapter failed due to overstressing.
- The bottom cap of the main piston was cut off.
- The lower over-pass microswitch was disassembled and was badly deformed, but its case was still connected

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to the main body. The upper part suffered only minor deformations.

- Both cases of the over-pass microswitch were displaced and badly deformed, but it was still connected to the main body.
- The pin was connected to the bore, although slightly rotated from its original position.
- The over-pass piston was intact.
- The servo-actuator piston was intact. The sleeve is intact.
- The pressure relief valve was intact.
- The extension was completely disconnected from the over-pass piston, as the microswitch case was crushed by impact forces against the ground.
- The pin remained attached to the bore.
- The over-pass piston was intact and remained connected to the extension. The servo-actuator piston was intact.
- The sleeve was intact.
- The pressure relief valve was intact.
- The extension remained connected to the over-pass piston and microswitch cam, although slightly deformed.

1.4.5.3. Red Main rotor servo-actuator.

- It has part number 109- 0110 -42-134 and serial number 6229.
- It has 2,001 total hours and 575 last major repair hours.
- This MRA is installed on the left side of the main gearbox. It has extensive ground impact damage, comparable to the damage on the yellow MRA.
- The two pins connecting the input cam were also found in their design location, although the lower portion is mostly displaced.
- The terminal assembly was bent, but still attached to the main piston. The main gearbox upright adapter also failed due to overstressing.
- Both micro-overpass switch cases were displaced and deformed, but it was still connected to the main body.
- The pin was partially connected to the bore and the over-pass piston remained intact.
- The servo-actuator piston was intact.
- The sleeve was intact.
- The pressure relief valve was intact.
- The extension was completely disconnected from the over-pass piston, as the microswitch case was crushed by the impact forces.
- The pin was still connected to the bore and the over-pass piston was intact (the lower pin is partially displaced and also visible).
- The over-pass piston was intact.
- The servo-actuator piston was intact.
- The sleeve was intact.
- The pressure relief valve was intact.
- The extension remained connected to the over-pass piston, but was crushed and fractured by the impact, along with the microswitch case.

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1.4.6. Destructive inspection to MRAs.

On June 5, 2019, the destructive inspection to the 3 MRA's was carried out at Collins Aerospace (Microtecnia) in Brugherio, Milan, Italy, being the Manufacturer's Assessors and the Accredited Representative (ANSV).

All 3 actuators were completely disassembled and the spool valves were checked for any signs of pre-existing failure and this activity was negative. No significant findings were recorded on any of them as corroborated by CT scan images, except for the crash damage present on all connections between the over-pass pistons, servo-actuators and microswitch cams.

A single part of an actuator was subjected to additional microscope examination in Leonardo Helicopters' laboratories only to confirm its failure mode, as it was too small to be visually examined with the available tools, but as its functionality is not critical for the servo-actuators to correctly operate, the outcome of the investigation was not affected anyway.

1.4.7. Drive systems

1.4.7.1. Main gearbox

- The planetary gear support and the 5 planetary gears were recovered and showed dirt embedded in the planetary gears and bearings, the planetary gear teeth did not show abnormal wear or fractures, they did not rotate freely, but showed a limited rotation similar to the bearing set, in both directions.
- On the sun gear teeth, most exhibited no abnormal wear or fractures, only two gear teeth showed an impact mark, the sun gear grooves had no abnormal wear.
- The main rotor shaft slots did not show abnormal wear.
- The ring gear remained attached to the lower case and showed no abnormal wear.
- The internal surfaces of the main gearbox were dirty and sooty due to exposure to the environment after the accident.
- For the bolts retaining the center bearing support case, the four bolt heads were not present so a baroscope was used and the opposite side of the support case was observed where the threaded terminals of these four bolts were present.
- The main gear remained attached to its platform.
- A section of the main bevel gear teeth was examined using a borescope; no anomalies were observed.
- The main bevel input pinion could not be examined using a borescope.
- The main bevel gear input spur gear and the spur gear teeth driving the tail rotor showed no anomalies.
- The rotor brake was recovered which contained the rotor brake disc, tail rotor drive adapter and spur gear. The rotor brake assembly showed thermal damage due to the post-accident fire. The Thomas coupling disc assembly remained attached to the forward adapter of the tail rotor drive system and showed impact deformation.

1.4.7.2. Combining gearbox.

- It was made up of multiple parts, there were large parts such as part of the combiner gearbox case with the input pinion and engine oil cooler fan still attached. The front of the diaphragm coupling remained attached to its respective input pinions.
- One crank gear was recovered and showed thermal damage.
- The engine oil radiator fans remained attached to their respective parts of the combiner gearbox case, it exhibited impact deformation and roughing.

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- The oil cooler fan belts were not present and were probably consumed by the post-impact fire.
- There was no abnormal wear on the teeth of the pulley gears.

1.4.7.3. Tail rotor gearbox and tail rotor controls

- The tail rotor gearbox was as one assembly.
- The input flange did not rotate with hand force as it exhibited bending due to deformation.
- The input flange contained the tail rotor drive system rear adapter.
- The outer end of the output shaft was fractured due to overload, the rest of the output shaft remained attached to the tail rotor hub.
- The tail rotor control links remained attached to the tail rotor gearbox, the links had continuity from the inlet control rod (from the boom) to its rocker arm, the links had continuity from the rocker arm to the slider assembly.
- The two-tail rotor pitch change links remained attached to the slider assembly. One of the pitch change links was fractured at its outer bearing and the second pitch change link was whole and its outer bearing contained a portion of a shaft pin, both pitch change links exhibited deformation.
- The tail rotor controls showed static deformation due to the impact and even under these conditions were free to move.

1.4.7.4. Tail rotor drive shafts

- The tail rotor rear drive shaft (number 3 according to IPD).
- The rear shaft was found in two pieces and was fractured near its forward end, the fracture is from overload, the forward areas of the rear shaft showed thermal damage.
- Three bearing supports remained installed at the front end of the rear shaft, two bearing supports were still attached to their uprights, where they separated from the rear shaft.
- The two rear bearings could be rotated by hand without any problems, the third rear bearing could be rotated by hand, but with difficulty, due to impact damage.
- The two bearings separated from their support could not be rotated manually, the rollers of the fourth rear bearing were present, although its case was not present, as well as the two seals; there were a total of 12 rollers on this bearing. The cover of the fifth rear bearing remained installed and its rollers were not visible.
- The forward end of the rear shaft remained connected to the adapter, the latter contained a Thomas coupling and a portion of the rear flange of the tail rotor drive intermediate rear shaft. The Thomas coupling exhibited continuity and deformation, but no fractures. The toothed connection between the tail shaft and the adapter was inspected under a stereoscope and the toothed profile of the adapter showed no evidence of abnormal wear.
- The Thomas coupling remained attached to the rear end of the tail shaft; this coupling was fractured and deformed, a fractured portion of the adapter (connected to the tail rotor gearbox input) remained attached to this Thomas coupling.

1.4.7.5. Tail rotor drive shaft

- According to the IPD it is the intermediate shaft (number 2).
- Only the front part of the intermediate shaft was recovered, which contained a bearing and its support. The fracture in the intermediate shaft was due to overload and showed thermal damage.
- The second bearing and its support were separated from the intermediate shaft.
- The teeth at the front end of the intermediate shaft showed no abnormal wear.
- Both roller bearings were visible, their flanges and seals were not present, there were a total of 12 rollers per

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bearing.

- The adapter, the Thomas coupling and a part of the No.1 drive shaft adapter were found as one piece. The Thomas coupling showed deformation and separation, but had continuity. The fracture of the No.1 drive shaft adapter was due to overloading.
- The grooves in the adapter showed no abnormal wear.
- In total, all 7 bearings and their supports were present in the debris.
- In total, all four adapters and their connections and bolts were present among the debris.
- The most forward adapter was seen in box 2 attached to the rotor brake.

1.4.7.6. Tail rotor.

- The two tail rotor blades remained attached to the hub and were complete from blade root to blade tip, both blades could be rotated on their rotation shaft.
- The tail rotor blade S/N R2374 had multiple impact marks on its leading edge and deformation of its pool, hub and trailing edge. The outer hub including the spherical bearing remained attached to the blade and the type of fracture was overload fracture.
- The tail rotor blade N/S P1409 showed less damage compared to the blade N/S R2374. Its trailing edge was deformed. The retaining bolt of the pitch change link was separated from the blade.
- The toothed portion of the tail rotor gearbox output shaft remained installed in the hub. The fracture showed evidence of overloading.

1.5. Hydraulic pumps.

1.5.1. Left hydraulic pump.

The left hydraulic pump remained attached to the lower case of the main gearbox, it showed thermal damage, the fixing fittings were removed but could not be disconnected due to the structure being bent so it was necessary to cut the structure to release it, once the pump was removed, it was observed that the drive shaft of the left hydraulic pump was bent and its grooves showed impact damage, no damage was observed, the pump data plate showed a part number 109-0760-42-105 and serial number See 3.

Disassembly of the left hydraulic pump:

- The exterior of the pump showed thermal damage due to the post-accident fire.
- The external fittings were removed from the pump and the inside of the bores showed no obstructions.
- The safety bolts were removed from the pump cover, showing the drive assembly, the drive veins exhibited no abnormal wear, the drive assembly bearing was present and showed no evidence of failure.
- The drive shaft cover was removed and the drive shaft was removed and this unit was intact and had no anomalies.
- The platen was not removed from inside the pump as there was no visible damage.
- The pressure regulator, spring, pin, cover and case were removed and showed no fractures.
- Degradation of the seal O material was observed in the area where they were installed.

1.5.2. Right hydraulic pump.

On July 26, 2019, destructive testing was performed on the right hydraulic pump at the NTSB facility in Washington, District of Columbia, USA, with the following findings:

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Soot was present on the outside of the hydraulic pump. The mounting flange, three of the four gores were fractured. The fourth mounting gore and bolt remained in its mounting gore. The bolt was removed and exhibited deformation. A small reservoir of hydraulic fluid was present in the pump body.

The drive shaft adapter slots remained installed and did not exhibit evidence of tooth fracture. The drive shaft could not be rotated manually. Safety wire was present in the hydraulic line connection fittings.

The technical data plate read as follows:

Model No. AP1.5V-01-02	Fluid MIL-H-5606E/MIL-H-83282
MFG P/N 4212402	Delivery 16 L/min
MFG Date 09/09	Speed 4200 RPM
Serial No. N/S See 3	Pressure 1500 PSI
Agusta P/N: 109-0760-42-105	Agusta Spec No. 109-0760-42

The small tank was removed and the inside of the pump could be observed. No metal debris was visible inside. The pump cover was removed, exposing the swashplate. No abnormal internal damage was observed on this or other internal surfaces. Remaining hydraulic fluid was observed inside. Once the pump cover was removed, the drive shaft was able to rotate without evidence of binding.

The swashplate barrel was removed. The spline adapter with the swashplate barrel showed no damage. The swashplate case showed a fracture that grew longitudinally (in the rotation shaft). The fracture was observed on both the outer and inner surfaces of the case, indicating that the fracture had grown completely through the case wall. This fracture is consistent with overstressing.

The drive shaft cover was removed. Remnant hydraulic fluid was observed on the inner surfaces; the fluid was red in color. Metal debris was found on the outer face, adjacent to the outer bearing race. The swashplate drive shaft was removed and exhibited no abnormal damage. The veins of the drive did not exhibit abnormal wear. The drive assembly bearing was present and exhibited no signs of failure. The pressure regulator was removed. The spring, pin, cap and case did not exhibit abnormal damage. “O" seals exhibited no damage.

2. Conclusions.

Up to the end of the investigation activities carried out at the Leonardo Helicopters facilities in Cascina Costa, Milan, Italy, from April 7 to 12, 2019 to the wreckage of the Agusta brand helicopter model A109S serial number 22174, registration number XA-BON, to the components inspected, no mechanical failures or anomalies were found that would have prevented its normal operation.

The evaluation carried out during the research activities is the result of a macroscopic visual and stereomicroscopic observation of the following components.

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[Logo: AFAC - Federal Civil Aviation Agency]

COMUNICACIONES | AFAC

SECRETARIAT OF COMMUNICATION AND TRANSPORT

Under-Secretariat of Transport
General Directorate of Civil Aviation
Aviation Accident and Incident Analysis Directorate

Exhibit E

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SECRETARIAT OF COMMUNICATION AND TRANSPORT

Under-Secretariat of Transport
General Directorate of Civil Aviation
Aviation Accident and Incident Analysis Directorate

Content

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1. Factual report on computed tomography.

The left and right-side yaw linear actuators, the left and right-side pitch linear actuators, and the yaw linear actuator underwent computed tomography (CT) scanning to document their internal conditions. On May 09, 2019, the findings were presented at a conference. The scanning work was performed at Varex, Chicago, Illinois, USA, under the direction of the NTSB.

Linear yaw actuator:

a. The LVDT is apparently not centered within its shaft.
b. The base of the ball screw was 4.01 mm from the retraction stop and 6.08 mm from the extension stop.
c. There is evidence of metal shavings within the ball screw cavity.
d. The movable brake plate pins appear to be hooked with the stationary plate notches.
e. There was no evidence of welding on the brush wire to element connections.
f. The engine segments in contact with the brushes appear to be rotated.
g. Some of the pins on the electronics board are displaced.
h. High density particles were observed on bearing # 2.

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Linear actuator number 1:

a. The LVDT did not appear to be centered within its shaft.
b. The base of the ball screw was 5.97 mm from the retraction stop.
c. There was no evidence of metal shavings within the ball screw cavity.
d. The movable brake plate pins appeared to be hooked with the stationary plate notches.
e. There was no evidence of welding present on the brush wire to join the element connections.
f. There was a medium density object present within the actuator body.
g. There was a high-density object present within the actuator.

Fig. 1.a. Two loose screws and a washer are observed.

Linear actuator number 2:

a. The LVDT shaft appears to be bent.
b. The base of the ball screw was 5.10 mm from the extension stop.
c. There was no evidence of metal shavings inside the ball screw cavity.
d. The movable brake plate pins appear not to be hooked with the notches in the stationary plate: the pins rest on the stationary plate.
e. There is evidence of weld present on the brush cable to join the element connections.
f. Some of the terminals on the electronic board are displaced.

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g. The wiring harness fixing screw appears to be broken.

Linear actuator number 3:

a. The LVDT shaft appeared not to be centered within its shaft.
b. The base of the ball screw was 5.20 mm from the extension stop.
c. There is evidence of metal shavings within the ball screw cavity.
d. The movable brake plate pins appear not to be hooked with the notches in the stationary plate: the pins were resting on the stationary plate.
e. There was no evidence of welding present on the brush wire to join the element connections.
f. Some of the electronic board terminals are displaced.
g. A weld anomaly was observed on one terminal of the electronics board.

Linear actuator number 4:

a. The LVDT shaft appears to be centered.
b. The base of the ball screw was 5.78 mm from the retraction stop.
c. There is no evidence of metal shavings within the ball screw cavity.
d. The movable brake plate appeared not to be fully hooked with the stationary plate - two pins appeared to be hooked with notches in the stationary plate - the remaining pin rested on top of the stationary plate.
e. There was evidence of weld present on the brush wire to join the element connections.
f. The engine brushes appeared to be damaged.
g. There were wires inside the actuator that appeared to be terminated with insulation extending beyond the end of the wire.

2. Destructive inspection of electromechanical linear actuators.

The group of investigators (NTSB, EASA and DGAC) and manufacturer's experts (Leonardo Helicopters and Honeywell), met at Honeywell's facility in Boyne City, Michigan, July 23-24, 2019, to perform the destructive inspection of the 5 electromechanical linear actuators, 2 roll, 2 pitch and 1 yaw.

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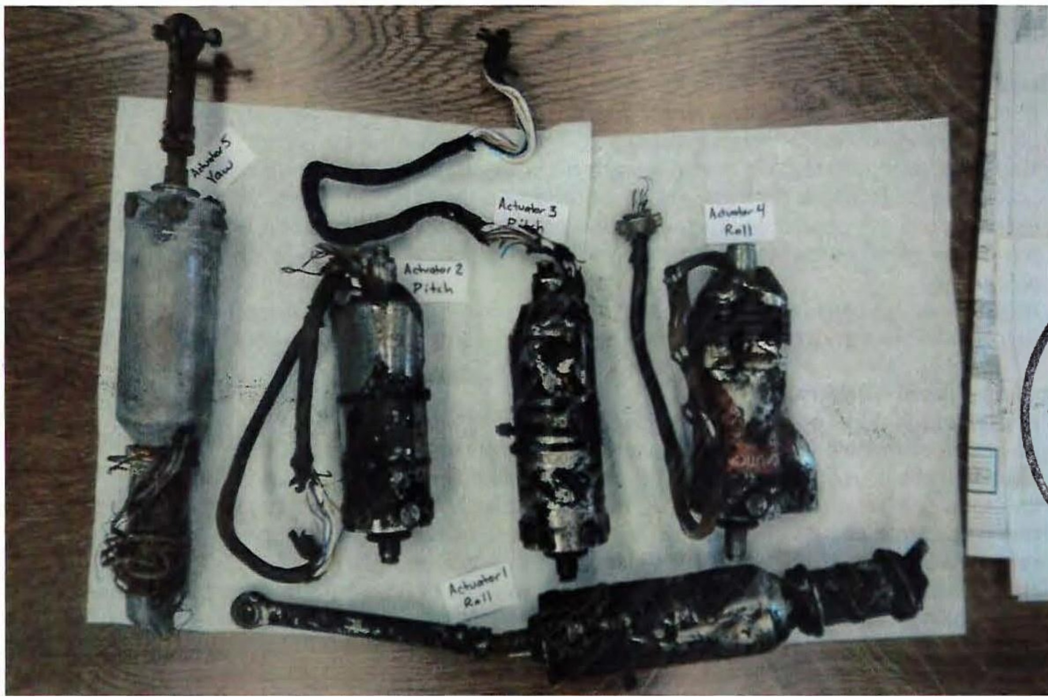

2.a The five electromechanical linear actuators as they were found

All references are from back to front, unless otherwise specified.

2.1. Left electromechanical linear roll actuator

- Left Position (P/N 4012373-909) N/S 0908L409
- It still had the link terminal connected to its output end. The lock nut, (toothed washer) and lock washer (locking tab) were present, but the safety cable was missing.

2.1.a. Left (SAS1) and right (SAS2) linear roll actuators

- The connecting tube remained attached to this actuator. A small portion of the right-hand linear actuator case (roll) was attached to the connecting tube. There was no safety wire in the connection nut of the connecting tube.
  - The connection tube was removed by Honeywell's expert.
  - The LVDT[1] was not protruding from the case and was not fractured.
  - The ball screw remained aligned with the alignment marks on the case.

2.1.b. The ball screw was observed in retracted position

  - The cover screws were removed (there was safety wire on each screw) and the cover was removed. Overall, the actuator body appeared to be in good condition.
  - The travel stop (attached to the ball screw shaft) was next to the extension side travel adjustment ring. This extension of the actuator was related to a bank to the left.
  - A piece of metal debris was found on the inside diameter of the case. The depth of the piece from the larger diameter end (where the long rod end is located) was approximately 2.165 inches.
  - A footprint was observed on the outer body of the actuator. The footprint started from the end of the body (where the end of the long rod is located) and was approximately 1.642 inches long, then continued in a zigzag pattern. The zig-zag pattern passed over a clear orange sheath covering the engine cable. It is likely that this damage occurred during removal of the cover.
  - The external support screws for the electronics board were missing, so the electronics board was loose at that end, however, it remained connected to the linear actuator body at the opposite end. The screws that were loose inside the body had their washer.

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2.1.c. Two front screws holding the card to the actuator body were not found in their design position

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- During the cutting of the band holding the wires together, a piece of black wire was found separated from the rest of the wires; one end had a hooked appearance, presumed to be the end that was connected to one of the 17 connection points on the electronic board. Terminal 11, where the black wire is normally connected, had no wires attached.
- Electrical continuity check:

Component	Measure
LVTD output continuity check:	645 ohms
LVTD excitation:	198 ohms
Brake:	short-circuit
Motor:	46 ohms
Diode function, normal:	1 ohm
Diode function, reverse:	1 ohm
Diode:	No significant change when changing polarity

- Functional testing:
    - Checking LVDT functionality.
        - ✓ When energized, the LVDT reading was approximately 5.9 volts. The reading should have been closer to approximately 2 to 2.5 volts.
    - Checking brake functionality.
        - ✓ The brake did not work when energized. The wiring was modified to remove the diode from the circuit, after which the brake was energized, but there was no movement (there was a short-circuit). Using a screwdriver through the access port was able to move it axially to disconnect it from the engine.
    - Checking engine functionality.
        - ✓ The engine was energized and attempted to rotate, but rotation was prevented by the brake structure.
        - ✓ Several screwdrivers were used to lift the brake structure away from the engine and the engine was re-energized, however there was no movement of the engine hub, but a response was felt (in the hand) that the engine was trying to move.
        - ✓ It was possible to move the threaded end of the engine in the direction of rotation, it moved to the top of the stroke, there being continuity from the top of the stroke, to the output end of the engine.
- Disassembly
    - The two screws and washers closest to the base of the linear actuator were installed on the electronic circuit board. The electronic circuit board was removed from the front case.
        - ✓ The threads of the screws that were attached to the electronic board had a clean appearance, the end of the screws was shiny, matching the thread connection to the actuator body.
        - ✓ For the screws that were loose, their threads showed debris on their surface.
        - ✓ On the front of the actuator, one of the two screw bores (the one on the inner side of the case) had raised material with thread trace.
    - The threaded end of the threaded rod was cut to facilitate separation of the engine case and the ball screw.
    - LVDT
        - ✓ When the ball screw was moved from one end to the other, the voltage changed from 8.7 V (full retraction) to 6.0 V (full extension). When the ball screw was stopped at mechanical zero, the voltage reading was approximately 7.6 V.

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- ✓ When the LVDT was tested, the voltage was zero below 1.0V.
- o Brake
  - ✓ The brake structure could move without restriction. The armature springs were functional.
  - ✓ The brake magnet was removed and its functionality was verified.
    - ☐ Power was applied to the magnet, but the armature did not adhere to the engine.
    - ☐ There was a short-circuit in the magnet assembly.
- o Engine
  - ✓ All four brushes were installed and intact.
  - ✓ For the engine installed in this actuator, the engine manufacturer is Koll Morgan (code 7738 4).
  - ✓ The rear bearing of the case could be rotated freely.
- o The key was present between the keyways in the ball screw and the rotor.
- o The ball screw and adjusting ring were removed. The ball nut exhibited smooth rotation with no evidence of binding. Debris was found on the adjusting ring and ball screw surfaces. The debris was collected for analysis.

2.2. Right electromechanical linear roll actuator.

- Right position (P/N 4012373-909) S/N See 3 118.
- The actuator case was fractured at its inner end. The outer end of the case was fractured and partially separated. The rope at the outer end was fractured.
- The ball screw keyway (anti-rotation feature) remained aligned with the alignment mark on the case.
- The outer end of the front case was fractured and separated near the O-ring groove, exposing the LVDT.
- On the remaining data label on the case, "24" was visible on the serial number line.
- A repair tag was found on the actuator case. The label was partially legible and readable:

Precision Accessory and Instruments
A PAG Company
Atlanta 404-767-5900
Repair Station ZV4R714M
www.precisionaccessories.com

- The cover screws were removed (there were safety wires on each screw) and the cover was forcibly removed with a hammer. The actuator body had dirt on parts of its surface, as well as the internal components with the stroke adjustment rings and the stroke stop.
- The stroke stop was next to the stroke adjustment ring on the extension side. The actuator extension correlates with a roll input to the left.

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2.1.d. Actuator external conditions 4 (roll 2, SAS2)

- The electronic board remained connected to the actuator body.
- Continuity test.

Component	Measure
LVTD output:	844 ohms
LVTD input (excitation):	197 ohms
Brake:	circuit was open
Motor:	circuit was open
Diode function, normal:	open
Diode function, reverse:	4 ohm
Diode:	No significant change when changing polarity

- Functional testing:
  - Checking LVDT functionality
    - ✓ The LVDT voltage showed approximately 11 V. The LVDT was moved manually and the reading showed 5.7 V. The decrease in voltage was consistent with the direction of LVDT movement from retraction to extension.
  - Brake functionality
    - ✓ When the brake was energized it did not make any movement. When observing the assembled brake in the port views it was verified that the skewed in the CT Scan images two pins were crimped and one pin was not.
  - Checking engine functionality.
    - ✓ The engine was energized and the result was that it did not perform in any movement.
  - Based on the results, the unit is not electrically functional.
- Disassembly
  - The brake cable was found broken where the wiring is located. The purple brake cable was not connected to the electronic board at port 12 but the port was covered with sealant.

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2.7.e. Ball screw found in right position

- The brake continuity test was confirmed. Brake wiring was connected to a power source; this brake functional test resulted in successful braking operation.
- The engine wiring was tested for continuity but the wiring remained open.
- The retaining nut holding the front casing to the rear case could not be removed due to deformation of the rear case. The nut and case were cut to facilitate removal and the front case was successfully removed.
- The engine hub remained with the rear case. The engine hub could not be rotated manually.
- The brake was retained with the front case. Thermally degraded grease was observed on the brake case bore and the ball screw.
- Soot was observed on the surface of the case. When viewed under the stereoscope, evidence of corrosion pitting was observed on the surface of the case.
- The ball screw nut could be rotated with hand force. Rotation of this nut exhibited roughness, but no evidence of binding. The ball screw was able to move its full stroke between the adjusting rings.
- The key was present between the keyways in the ball screw and the rotor.
- The brush block showed a See 3 code (Koll Morgan)
- The engine was damaged due to an external impact inside the rear casing causing a deformation.
- The following numbers were observed on the outer face of the engine
- See 3
- With power applied to the LVDT, the voltage changed from 12.5 V (full retraction) to 6 V (full extension). The LVDT sleeve moved into the casing during [external] case removal.

2.3. Left electromechanical linear pitch actuator

- Left position (P/N 4012373-909) S/N See 3 -333
- The actuator case was fractured at the inner end. The threads on the outer end were fractured.
- The outer end of the front case was fractured and separated near the "O" seal groove exposing the LVDT.
- There was no legible information on the data label remaining on the case.
- The cover screws were removed (safety wires were present on each screw) and the cover was removed with the support of a hammer.
- The travel stop was next to the retraction side adjustment ring, corresponding to pitch down.
- There was dirt on the internal components, including the travel stop and ring adjustment, but there was less dirt compared to Actuator 4.
- Continuity test

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Component	Measure
LVTD output:	896 ohms
LVTD input (excitation):	207 ohms
Brake:	72 ohms
Motor:	780 ohms
Diode function, normal:	60 ohms
Diode function, reverse:	12.5 ohm
Diode:	No significant change when changing polarity

- Functional testing
  - Checking LVDT functionality
    - ✓ When the LVDT is in a fully retracted position, the voltage should be 2V.
    - ✓ When the LVDT was activated, the voltage reading showed 9.4V. When the LVDT was manually moved, the reading showed approximately 8V. The direction of LVDT movement was consistent with the expected voltage drop. Further manual movement of the LVDT resulted in a 4.5 V reading. At the end of the LVDT could be observed exiting the front case.
  - Brake functionality
    - ✓ When energized, the magnet was energized to disengage from the engine hub. When power was removed, the armature reattached to the engine hub.
  - Checking engine functionality
    - ✓ The ball screw did not extend and retract when power was applied to the engine. A slight rotational movement of the engine hub was observed when the engine was energized. After the LVDT was manually moved and the engine was energized, a rumbling sound was heard coming from the engine, but no movement of the ball screw was observed. A slight movement of the stroke stop was observed, consistent with engine continuity.
- Disassembly
  - The rear case was cut to facilitate removal of the front case.
  - The ball screw nut could be manually turned on the ball screw, but there was evidence that it was stuck initially. Soot was observed on the visible portion of the ball screw. The ball bearing in the front case could not be turned.
  - The key was present between the keyways, on the ball screw and rotor.
  - The engine manufacturer is Koll Morgan (code 11384).
  - The rotor was removed and the number See 3 on the engine hub could be observed.
  - The rotor had surface damage with the appearance of corrosion.
  - The rear case bearing could be rotated, but showed signs of roughness.

2.4. Right electromechanical linear pitch actuator

- Right position (P/N 4012373-908) S/N See 3.158

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- The actuator case was fractured at the inner end. The threads on the outer end were fractured.
- The outer end of the front case was fractured and separated near the "O" gasket grooves, exposing the LVDT.
- There was no data label on the case.
- The cover screws were removed (there were safety wires on each screw) and the cover was removed with the use of a press.
- Soot was present on the surfaces of the inner side of the actuator body. Soot was also present on the internal components, including the travel stop and adjusting rings.
- The travel stop was found next to the retract side adjustment ring which corresponds to the down pitch position.
- Continuity test

Component	Measure
LVTD output:	open circuit
LVTD input (excitation):	0.2 ohms (shorted)
Brake:	76 ohms
Motor:	open circuit
Diode function, normal:	65 ohms
Diode function, reverse:	13 ohm
Diode:	No significant change when changing polarity

- Functional testing
  - Checking LVDT functionality
    - ✓ The LVDT reading showed approximately 29 mV, but was probably wrong because the LVDT had an open circuit.
  - Checking brake functionality
    - ✓ When energized, the brake did not operate. Mechanical movement of the engine hub did not result in movement of the brake.
  - Checking engine functionality
    - ✓ When energized the engine did not produce any movement in the hub.
  - Based on these results, the unit did not operate electrically.

- Disassembly
  - The rear case was separated from the front case.
  - The engine was struck inside the rear case due to deformation of the rear case.
  - The number "3758" was visible on the outside of the brake case.
  - The ball screw nut could be turned by hand with no evidence of binding. The ball screw nut had evidence of reddish colored grease and thermally degraded grease. The bearing in the front case could be rotated freely.
  - The key was present between the keyways in the ball screw and the rotor.
  - The ball screw and adjusting ring were removed. The LVDT exhibited discoloration consistent with temperature damage.

2.5. Electromechanical linear yaw actuator.

- Single position (P/N 4012373-905) S/N See 3 158
- The actuator showed external thermal damage. The connection tube was removed and the outer end of the LVDT was visible.
- The case screws were removed by hand (no torque). Safety wiring was present on each screw. The case was removed.

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- The two ring-type gaskets on the case were thermally degraded and disintegrated during removal of the case. The case was removed using a press.
- The surfaces of the linear actuator body and internal components showed thermal damage. Soot was observed on the surfaces of the internal components.
- Material was observed on the actuator case, possibly resolidified welding, on the inside diameter of the case.
- The electronics board was present, but some of the terminals had separated from the lacquer. Continuity checks were not performed due to thermal damage to the circuit board as well as the wires.
- The carriage stop was approximately halfway between the two adjusting rings.

2.1.f. The ball screw was found in intermediate position

- The yaw actuator was not functionally tested. The group discussed and agreed that no further disassembly would be performed at this time due to the damage and evidence of indication that was observed.

2.6. Findings.

a. On the helipilot control panel, the SAS1 and SAS2 systems default to the OFF position when power is lost to the helicopter. It should be noted that the default ATT HOLD switch position defaults to the ON (up) position when power is lost.
b. The SAS1 roll actuator was found to roll to the left and the SAS2 roll actuator was found to roll to the left.
c. The SAS1 pitch actuator was found nose down and SAS2 pitch actuator was found nose down.
d. The pitch actuator of SAS1 was found in the intermediate position.
e. On September 30, 2019, the NTSB accredited representative advised that he asked Precision Accessory and Instruments in Atlanta, Georgia, if there is evidence of loose screws from the electronic cards in previous repairs, stating that Honeywell reviewed over 5,000 records of repairs performed on linear actuators at Honeywell and Otto facilities, only finding only one record where it was noted **"missing screws FPN: 2504349-5 2" and "washers, missing locking - PFN: 0164-2,"** but does not specify whether the screws were found inside the actuator case or not installed at all.

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3. Factual report of SAS1 linear roll actuator inspection

The group of investigators (NTSB, EASA and DGAC) and manufacturer's experts (Leonardo Helicopters and Honeywell). at the conclusion of the meeting held at Honeywell's Boyne City, Michigan facility on July 23-24, 2019 left the following task:

3.1 SAS1 Linear roll actuator: Loose internal screw affecting helicopter performance

Leonardo Helicopters sent its report dated October 15, 2019, related to the tests performed to the SAS1 luffing actuator, which when disassembled presented in its interior two loose screws, these screws by design hold the electronic card to the actuator body.

Investigators recovered from the accident site the 5 linear actuators (Pitch LH/RH, Roll LH/RH, Yaw), which were disassembled and inspected during the visit to the manufacturer's (Honeywell) facility in Boyne City (Michigan) - USA) from July 23-24. Representatives from LH, DGAC, NTSB and EASA joined Honeywell personnel during this activity.

The activities, led by the NTSB, focused on identifying any signs of possible malfunction of any of the 5 linear actuators, especially the two yaw actuators, as witness reports indicated possible yaw shaft oscillations followed by an abrupt left roll maneuver of the helicopter. As the main finding, the right roll actuator had 2 of the 4 screws holding the control circuit board in secured position to the case which were found completely unscrewed (as confirmed by the preliminary results of the NTSB led investigation) loose inside the outer case, the metal circuit board and the LVDT (Linear Variable Differential Transformer) case. This is confirmed by the preliminary evidence provided by the CT scan.

As one of the actions to follow after the activity performed, Honeywell and Leonardo were asked to analyze the possible effects of the screws that unscrewed when moving freely on the terminals of the electronic card of the linear actuator and the behavior they cause in the helicopter.

The analysis of the effect of a loose screw touching the terminals of the electronic board was performed jointly by LH and Honeywell.

3.2 System description.

This section provides a description of the lntegrated Flight Control System used in the Leonardo Al09S helicopters. The integrated flight control system (IFCS) is composed of a helipilot system, a flight director system and a means of coupling the two systems to provide automatic flight path control.

The integrated flight control system provides stabilization in all three attitude axes (pitch, roll and yaw) and trajectory control. Automatic trajectory mode commands are provided by the flight director computer, thus integrating the helipilot system with the flight director/instrument system. Both stabilization and flight path calculations are programmed throughout the helicopter's flight regime for optimum performance.

The helipilot system provides stability and control through three types of operation: (1) stability augmentation (SAS). (2) attitude hold (ATT) and (3) automatic flight path control when in coupled mode (CPL). The flight director performs all flight path command calculations.

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Inputs to the computer from the altitude sensor, speed sensor, collective position synchronization, gyroscopes and navigation radios are processed to provide attitude change commands to the helipilot computers and/or the attitude director indicator (ADI). The modes are filtered by illuminated buttons integrated to the mode selector between the various system components shown in Figure 2.1.

The Primary Flight Display System (PFDS) provides display of heading, course, radius, pitch and roll attitude, rate of turn, heading deviation, glide slope deviation, go/no-go indications, altitude and vertical speed.

The helipilot (HP) computers provide all calculations for pitch, roll and yaw stabilization, attitude hold and linkage to the Flight Director computer. In addition, the computers provide the necessary signals to move the pitch, roll and yaw linear actuators.

The two computers provide dual stabilization in the pitch and roll shaft, and simple stabilization in the yaw shaft. Both computers are identical and interchangeable with each other. The yaw circuit is not present in the position of computer No. 2.

Linear actuators are extendable piston-type devices driven by an engine and are installed on the aircraft control links in a series arrangement. Electrical commands from the helipilot computers drive the actuator engines to extend or retract the control links that position the aircraft controls in the desired maneuver. Position feedback to the position control loop (servo loop) of the helipilot is provided by a linear differential variable voltage transformer (LDVT). An electromechanical brake releases the engine for operation when power is applied to the helipilot coupling.

3.3. Analysis of a loose screw touching the electronic board terminals

Investigation of the SAS1 linear roll actuator (P/N 4012373-909, S/N See 3 409) highlighted that 2 of the 4 screws holding the electrical control plate to the actuator body were completely unscrewed and moved freely on the outside between the metal actuator body and the LVDT case. The CT scan confirmed this result.

The research team asked the Linear Actuator manufacturer (Honeywell) and the helicopter manufacturer (LH) to perform a study of a possible contact between one of the two screws and one of the terminals of the electronic board.
The study of the contact of the loose screw with one terminal of the board was performed in two steps:

1. Honeywell analyzed the impact on the behavior of the Linear Actuator (e.g., input to the Helipilot computer).
2. LH analyzed the impact of Linear Actuator behavior on the Helipilot computer/helicopter

3.4. Analysis of helipilot performance.

The first step consisted of an analytical review of schematics and drawings with the objective of completing the general study by performing specific tests on a linear actuator.

Once the plan was identified, the experiment was carried out, using the necessary equipment to evaluate the behavior of the linear actuator loop control position in case of failure.

The nine conditions identified by Honeywell as representative of all possible short-circuits on the electronic board terminals are:

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Condition Nº1: Failure due to a possible contact between terminal 1 and ground on the actuator electronics board. This condition was simulated by reproducing a short-circuit between terminal 17 of the Helipilot and ground.
Result: The linear actuator remains in the initial position.
Note: once the short-circuit is eliminated, the linear actuator is fully operable and controllable.

Condition Nº2: Failure of a possible contact between terminal 1 and terminal 2 on the actuator electronics board. It was simulated by reproducing a short-circuit between terminal Nº16 and Nº17 of the Helipilot.
Result: The linear actuator extends and reaches its full travel stroke in less than 1 second.

Condition Nº3: Failure of a possible contact between terminal 2 and ground on the actuator electronics board. It was simulated by reproducing a short-circuit between terminal 16 of the Helipilot and ground. Result: the linear actuator remains in its initial position.
Note: Once the short-circuit is eliminated, the linear actuator is fully operational and controllable.

Condition #4: Failure of a possible contact between terminal 9 and ground on the actuator electronics board. This condition has no effect at system level because the 26 VAC excitation return is connected to helicopter ground.

Condition No. 5: Failure of a possible contact between terminal 9 and terminal 10 on the actuator electronics board. It was simulated by reproducing the loss of 26 VAC voltage between the external connector of the linear actuator Pin U and V (i.e., the voltage between terminals U and V equal to 0V).
Result: The loss of 26 VAC caused the disengagement of the affected SAS and the activation of the linear actuator brake.

Conditions Nº6: Failure of a possible contact between terminal 10 and ground on the actuator electronics board. It has been simulated by reproducing the voltage loss of 26 VAC at connector U of the external connector of the linear actuator (i.e., a voltage between terminals U and V equal to 0 V).
Result: the loss of 26 VAC caused the unlatching of the affected SAS and the activation of the linear actuator brake.

Conditions #7, 8, 9: Failure of a possible contact between:
Terminal 4 (C1 +) and ground on actuator terminal board.
Terminal 8 (C2 +) and ground at actuator terminal board
Terminal 4 (C1 +) and terminal 5 (C2 +) on the actuator terminal plate

These conditions cause permanent damage to the Helipilot circuits used to drive the engine (DC) of the Linear Actuator. For this reason, the experimental evaluation was not performed.

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At the system level, damage to the Helipilot circuitry results in loss of volt age to the DC-Engine of the Linear Actuator, therefore, in the actuator shaft position freezes.

Failure modes induced by short-circuits in the linear actuator electronics board were analyzed. Whenever possible without causing damage to system components and/or test setup elements, experimental evaluation was performed. The results of the analysis and experimental testing highlighted that few failure modes result in loss of Helipilot's ability to control the linear actuator with fault (i.e., hardover) or integrated flight control system (IFCS) disconnection (affected channel).

3.5 System-level impact assessment.

The helicopter's linear actuators were subjected to a complete investigation activity:

1. Based on the preliminary CT scan results, a decision was made to perform a complete disassembly of the linear actuators which was performed at Honeywell's Boyne City facility. This activity highlighted the loss of two electronic board screws from the SAS1 roll linear actuator.
2. Honeywell and Leonardo performed a two-step study on the effect of a loose screw touching the pins on the terminal board: the worst-case scenario outcome of the analysis is a possible permanence of the linear actuator failure. Disconnection of the integrated flight control system (affected channel) is also possible.

3.6 Helicopter-level impact assessment.

As verified in the A109S helicopter certification framework, none of the system level effects identified above result, by themselves, in a loss of control in flight.

However, from the evidence gathered during the investigation, it is confirmed that one SAS was declared inoperative (after performing the fault isolation activity in accordance with the instructions provided in the helicopter's Maintenance Manual) deeming further evaluation to be necessary.

The following factual considerations apply:

In the event that an SAS is declared non-operational, the Operator's Minimum Equipment List establishes the dispatch conditions [including Flight Manual (RFM) limitations].

Only flights in VFR conditions should be planned and flown attentively (indicated speed up to 128 knots and/or rate of climb 1,000 ft/m in, flying above 500 ft above the ground) or manually in all other conditions.

<u>Therefore, if only the RFM (Flight Manual) limitations apply with respect to an operational Helipilot, disconnection of the Helipilot or the Linear aileron actuator in "hardover" cannot result in a loss of control in the Helicopter's flight.</u>

3.7 Conclusions.

Short-circuit induced failure modes within the linear actuator electronics board have been analyzed. Whenever possible without damage to system components and/or test setup elements. experimental evaluation has been performed.

The results of the analysis and experimental testing highlighted that few failure modes result in the loss of the helipilot's ability to control the linear actuator presenting the failure (i.e., "hardover") or disconnection of the AFCS system.

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4. Factual report of SAS1 linear roll actuator body inspection.

The group of investigators (NTSB, EASA and DGAC) and manufacturer's experts (Leonardo Helicopters and Honeywell), at the end of the meeting held at Honeywell's facilities in Boyne City, Michigan, July 23-24, 2019, made the recommendation to perform an analysis of the body of the SAS1 linear roll actuator, to find out why the two screws inside the actuator were found loose, the results are as follows:

4.1. SAS1 linear actuator case, electronics board and mounting screws, spacers and lock washers.

On December 10, 2019, the NTSB materials laboratory made Report No. 19-067 wherein it documented the nature of the loose screws found during disassembly of the SAS1 linear roll actuator; the electronics board was found to be fixed in place with two screws installed on side 2 of the actuator body. A spacer was present between the electronics board and the actuator body, as well as lock washers present under each screw head.

During disassembly of the SAS1 linear roll actuator it was observed that the side 1 bolts were not installed, moreover one side 1 bolt was loose in the front cavity of the actuator case 1 and the other bolt came out of the actuator body and fell to the floor during disassembly. Although a side 1 washer was observed in the CT Sean images, none of the side 1 lock washers were recovered. The threads of the side 1 bolts were evenly coated with particles and debris, consistent with being loose within the actuator body cavity. In contrast, the threads of side 2 bolts were largely clean and free of particles and debris, which is consistent with having been threaded and fastened in their respective gores. The screw heads are documented to show no damage. The spacer on side 1 is documented in figure 4.1.c. and 4.1.d.

The securing screws are steel, flat head Phillips type with 1- 72 UNF[2] threads. The grip length is approximately 0.173 inch, measured with a dial gauge, the electronic board is approximately 0.038 thick, the spacer is approximately 0.062 thick, and the washer is approximately 0.020 thick. The combined thickness of the circuit board, lock washer and spacer is approximately 0.120 inches.

Digital microscope images of the top and bottom sides of the electronics board show that the screws and washers were installed. The mounting bores are labeled according to the assembly orientation. Close-up microscope images of the 1-side mounting bores are shown in Figures 4.1.e. The marks on the top side of the circuit board are consistent with the imprint marks created by the compression contact between the lock washers under the screw heads.

[2] Unified Thread Standard defines a standard thread form and series - along with allowances, accuracies and designations - for threaded fasteners commonly used in the U.S. and Canada.

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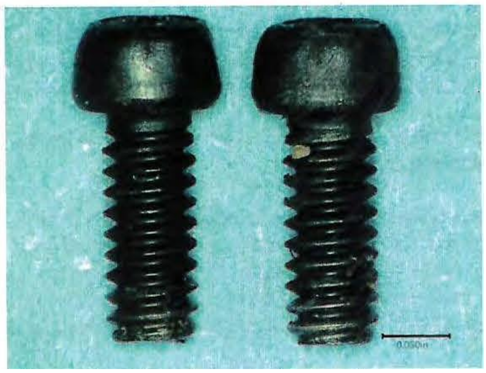
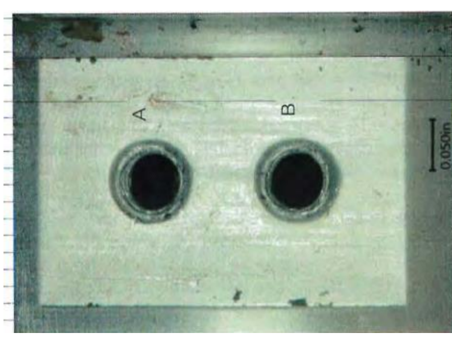
Digital microscope image of the electronics board mounting area on the front case of the actuator 1; the threaded mounting bores are lettered for identification purposes in accordance with Figure 4.1.d. Figures 4.1.e shows a closer top-down view of the mounting bores. Some leftover material was observed in the side bore of 1A. Higher magnification oblique angle views of each mounting gore. As revealed in the images, the threads in the first two of the side actuator bores 1A and B are shown cut. The threads in the side mounting bores 2A and B are fully formed.

For documentation purposes, samples of the metallic residues observed on the ball screw were located.

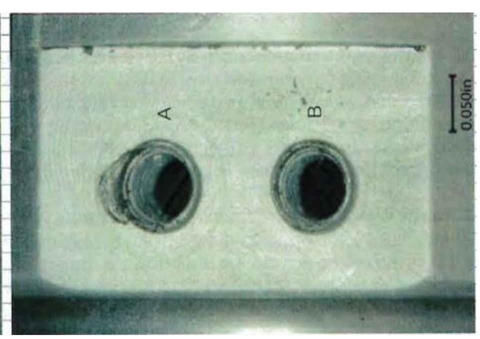


4.1.a Microscopic digital image of the screws removed from side 2.

4.1.b Microscopic digital image of the screws removed from side1



4.1.c. Side 2 of the actuator body (see 4.1.b.)



4.1.d. Side 1 of the actuator body (see 4.1.b.)

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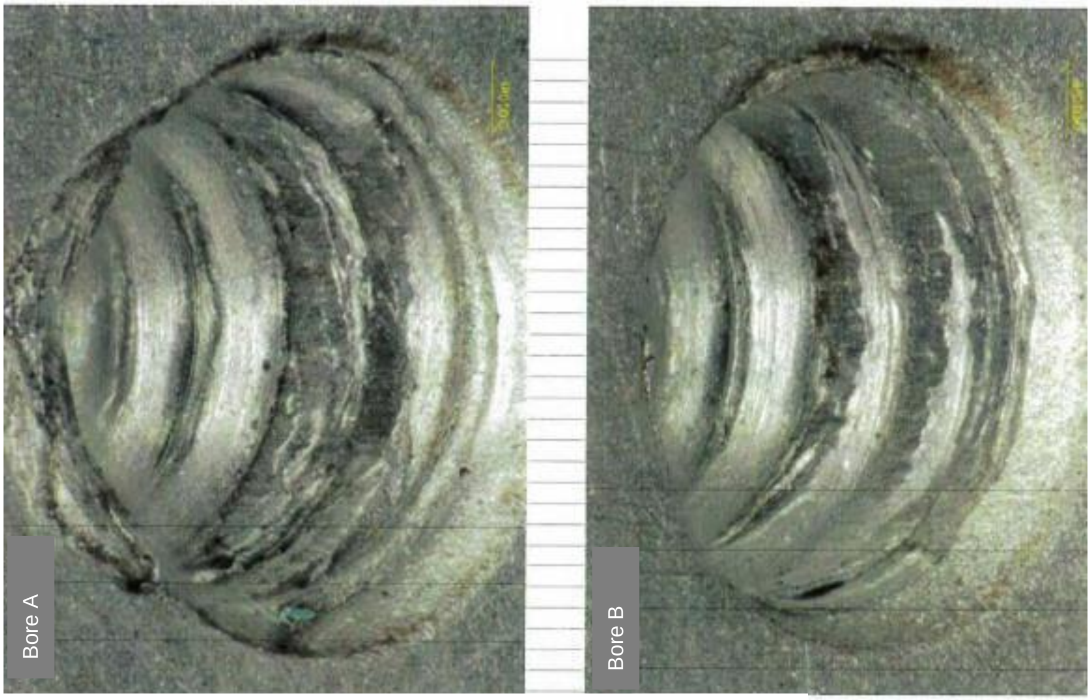

4.1.e. Images of the electronics board mounting bores side 1

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